PROCESSED DATA FROM THE STRONG-MOTION RECORDS OF THE SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978

FINAL RESULTS

1979

CALIFORNIA DIVISION OF MINES AND GEOLOGY

SPECIAL REPORT 144
VOLUME 1

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SPECIAL REPORT 144

PROCESSED DATA FROM THE STRONG-MOTION RECORDS OF THE SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978

FINAL RESULTS

1979

IN THREE VOLUMES

By

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FOREWORD

Special Report 144 of the California Division of Mines and Geology is the first final report of processed strong-motion data collected from an important earthquake by the California Strong Motion Instrumentation Program.

The Santa Barbara Earthquake of 13 August 1978 produced the first significant seismic motions recorded in structures instrumented with central recording accelerographs using multiple channel remote sensors.

This report contains the first automatically reconstructed accelerograms. This technique marks a new era in strong-motion record handling and makes possible ultra-precise processing without photo-enlargement. This program is one part of the system perfected by the California Division of Mines and Geology for the initiation of data processing using reassembled records.

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ACKNOWLEDGEMENTS

The authors wish to acknowledge the help of the Seismic Engineering Branch, U.S. Geological Survey, for making available its standardized routine computer programs, and to extend particular thanks to A. Gerald Brady and Virgilio Perez for their personal assistance.

The development of the mathematical logic for the BUTTER Program used in the automatic reassembly of the multiframe accelerograms was carried out under contracts from the California Division of Mines and Geology and the U.S. Geological Survey to the firm of IOM-TOWILL, Santa Clara, California. A. Gerald Brady of the U.S. Geological Survey performed several studies on film accelerogram reassembly during the period 1976-78 and also furnished the initial form of the program prior to modification. William R. Roseman of IOM-TOWILL provided careful assistance to the first author of this report during development and implementation of the detailed diagnostics required to validate the reassembly procedure.

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INTRODUCTION

On 13 August 1978 a moderate magnitude earthquake (ML = 5.1, Cal Tech Seismological Laboratory) occurred in the ocean 6 km south of Santa Barbara, California. The earthquake, originating at 22:54:52:4 ±0.1 second (GMT), had a focal depth of 12.5 ±3 km and was located at latitude 34.37° N and longitude 119.72° W (±2 km) (Lee and others, 1978).

Building damage generated by the earthquake was generally moderate and consisted mostly of broken glass and plaster. The approximate area affected by the 13 August earthquake is shown in Figure 1.

The Santa Barbara area has a moderate extent of instrumentation which includes 27 accelerographs within 90 km of the epicenter (Figure 2). Eleven accelerographs were triggered by the 13 August main event: eight of these instruments belong to the California Division of Mines and Geology (CDMG), one belongs to the Southern California Edison Company, one to the U.S. Bureau of Reclamation and one to the U.S. Geological Survey. Three CDMG stations in the Santa Barbara area recorded motions significant enough to warrant digitization (Figure 3): (1) Santa Barbara-Freitas Building, (2) Santa Barbara-UCSB North Hall Building and (3) Santa Barbara-UCSB Goleta. This report presents analyzed data from records of earthquake motions at these stations. The graphics in this report include uncorrected accelerations, corrected accelerations, velocities and displacements, response spectra, Fourier Spectra, and velocity-response envelope spectra.

The Santa Barbara-Freitas Building and USCB North Hall stations are reinforced concrete shear wall buildings, instrumented with central recording systems (Kinemetrics model CRA-1) monitoring nine channels each. The Santa Barbara-UCSB Goleta freefield station is instrumented by a three-channel strong-motion recorder (Kinemetrics model SMA-1) housed in a lightweight prefabricated metal shop building on a concrete slab floor.

The highest peak ground and structure accelerations generated by the August earthquake were in the Santa Barbara-UCSB North Hall buildings; corrected peak accelerations expressed in gravity (g), are 0.40g and 0.96g in the north-south direction on the ground floor and roof, respectively. Corrected peak ground accelerations from the Santa Barbara-UCSG Goleta freefield site, located approximately 1250 m northwest of UCSB North Hall, are 0.35 g north-south, 0.29 g east-west and 0.14 g vertical. The corrected peak accelerations are maximum in the east-west direction at the Santa Barbara-Freitas building and registered 0.23 g in the basement and 0.65 g on the roof.

Data from the three stations described in this report indicate that accelerations generated by the Santa Barbara earthquake did not attenuate with increasing epicentral distance; however, this phenomenon only applied to local areas less than 20 km from the epicenter. The Santa Barbara-Freitas building is the closest station to the epicenter (6 km), yet it experienced accelerations significantly less than stations on the UCSB campus at distances approximately twice as great. The increase in ground acceleration that occurred as epicentral distance increased can be interpreted as the result of source radiation effect and of azimuthal distortions of the peak amplitudes due to local geologic structure. A similar explanation for the locally intense ground accelerations during the earthquake is presented by Miller and Felszeghy (1978, p. 2-3). Several investigators (for example, Cloud and Perez, 1971; Jackson, 1971; Lysmer and others, 1971; Maley and Cloud, 1971; Hudson and Udwadia, 1974) have described similar situations or geologic conditions that lead to locally high ground acceleration. The Santa Barbara coastal and channel region, part of Transverse Ranges Province, has a complex structural history (Vedder and others, 1969;

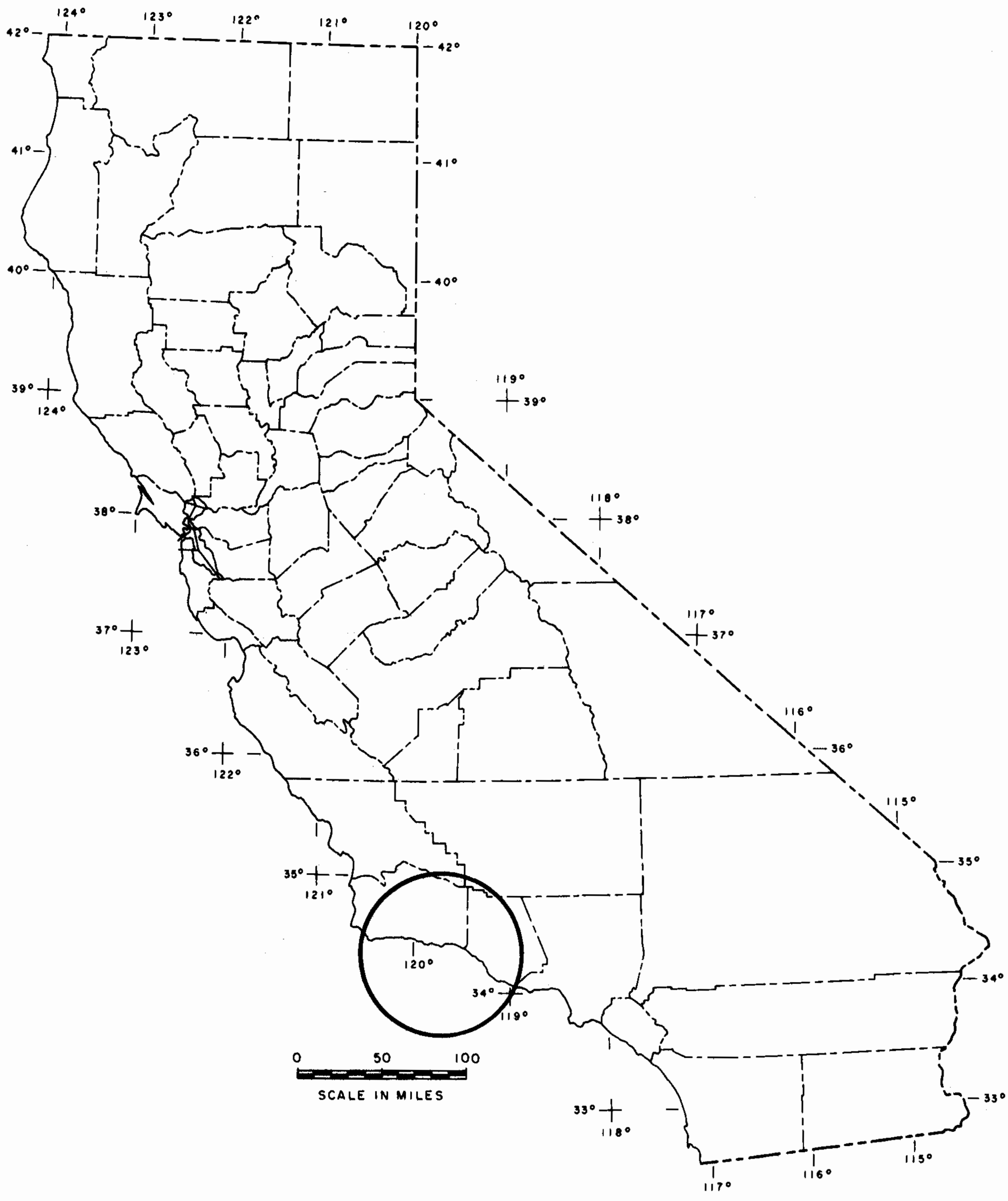


Figure 1. Outline map of California showing region of interest (circle) for the 13 August 1978 earthquake.

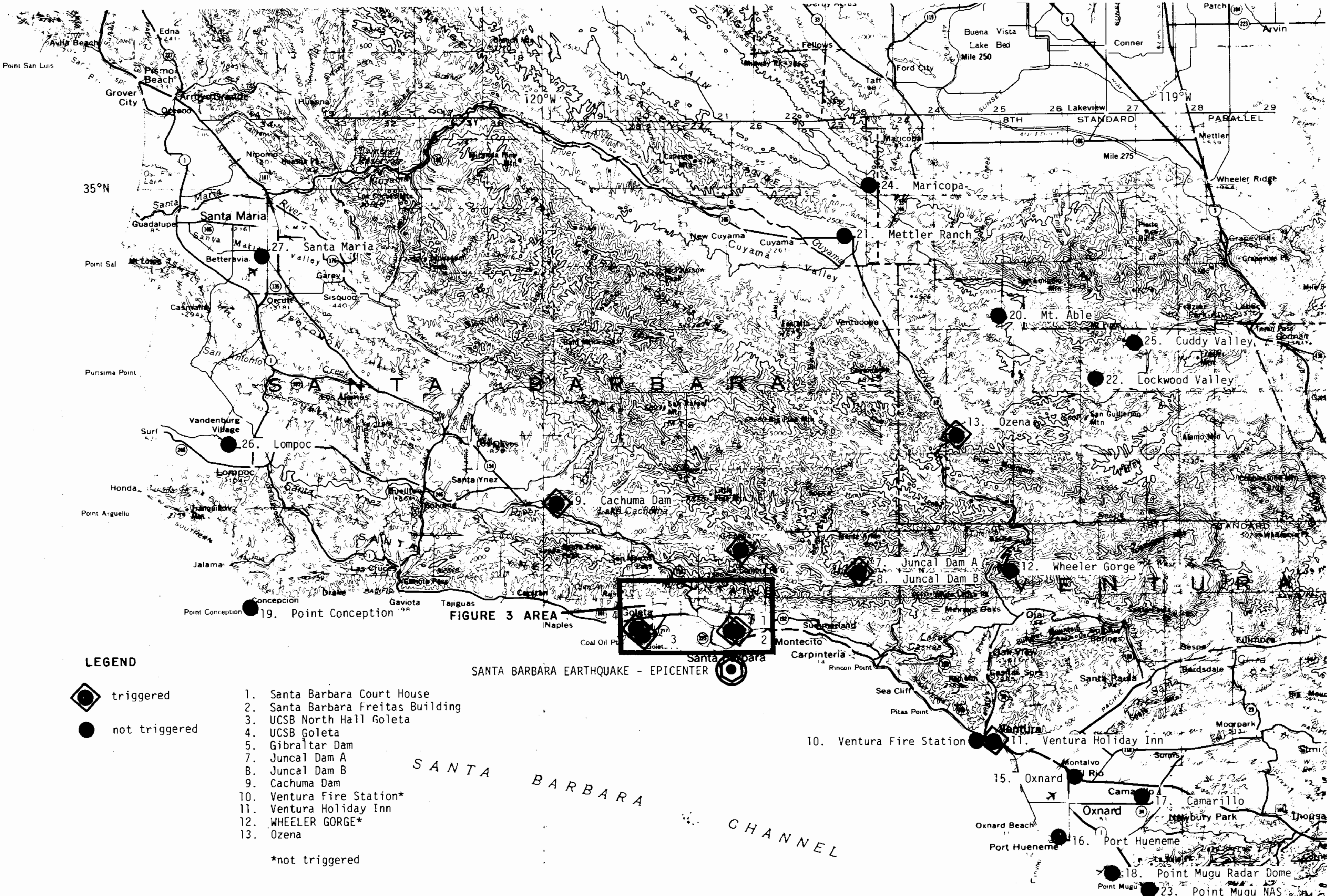


Figure 2. Locations of the strong-motion stations in the Santa Barbara region. Eleven stations (diamonds) were triggered by the earthquake of 13 August 1978. [Map scale 1:750,000].

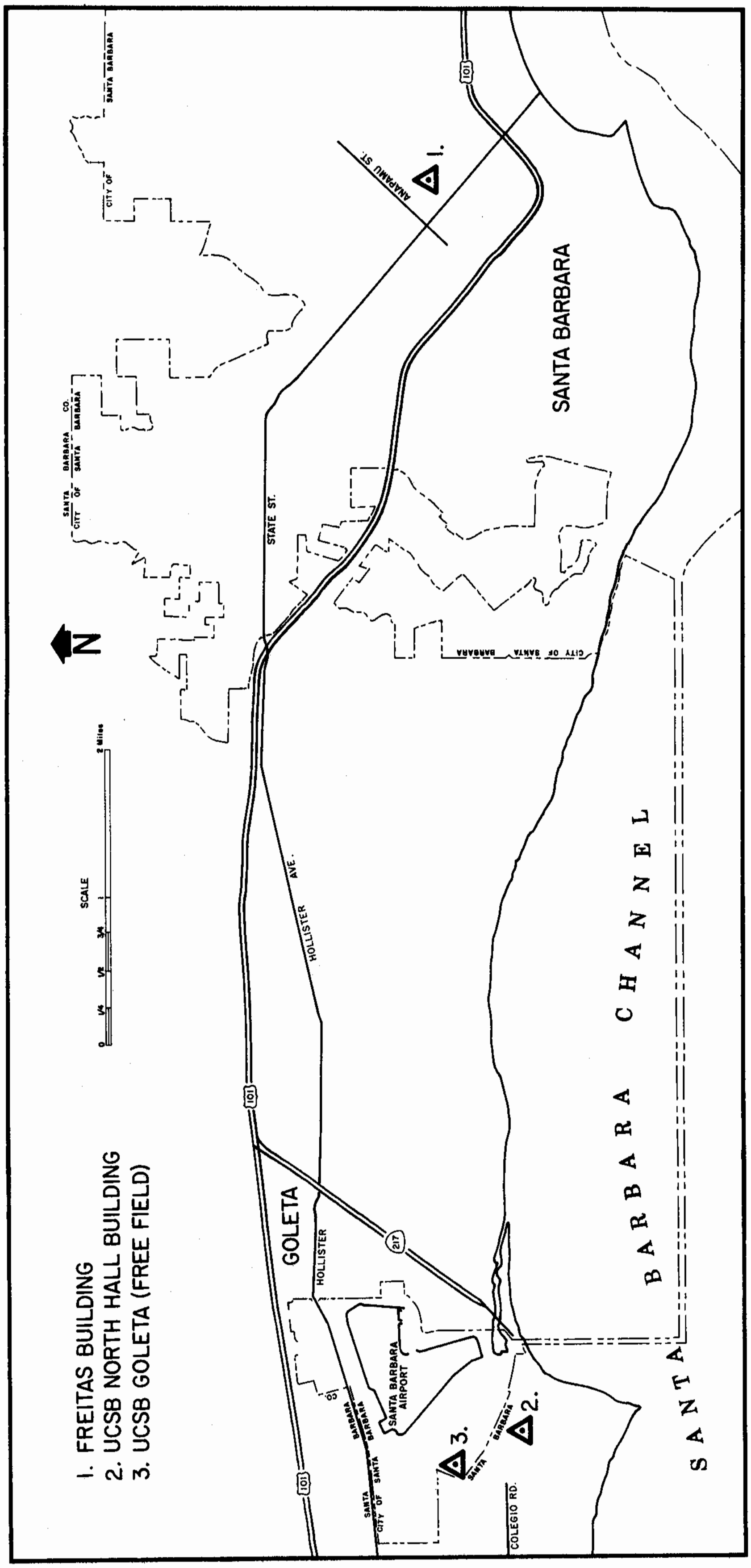


Figure 3. Location of CDMG Stations included in this report.

Campbell and others, 1979; Jennings and others, 1975, 1977). The local geologic structure in the epicentral region is an east-west trending compressionally deformed sequence of Cenozoic marine rocks which could act as a wave guide and in this way possibly produce variations observed in the amplitudes.

STRONG-MOTION RECORD PROCESSING

INTRODUCTION

Strong-motion record processing for the Santa Barbara earthquake of 13 August 1978 is described in four steps (Figure 4). This section lists the central features of each procedure. Descriptions of the corresponding computer programs, numerical tests and validation procedures are contained in reference memoranda (Appendices A and B).

DIGITIZATION

To obtain the least possible noise and long-period variations during conversion of strong-motion film records into machine readable form, accelerograms from the 13 August earthquake were digitized from first-quality photo-contact copies of the original records (Porter, 1978). These copies were made on a stable mylar base 0.1 mm (0.004 in.) thick, with a dimensional variation of less than 0.02 percent, as determined by studies of the U.S. Geological Survey Seismic Engineering Branch (U.S. Geological Survey, 1976). Digitization was performed with the aid of a laser-beam digitizer operating in line-following mode. This digitizer, with its ultra-high resoluiton (minimum step size one micrometer with an RMS variation of about 10 micrometers), was able to process records at their original scale and thereby avoid any distortions which would otherwise be introduced by photo enlargement.

The line-following mode provided digitized points at approximately equal spacing along the trace, but with extra dense spacing around sharp changes in curvature such as at peaks. The average step size during digitizing was approximately 20 micrometers, equivalent to 500 steps/second. Reference traces and butting lines (described later) contained no signal. Consequently, the step size during their digitization was increased to about 80 micrometers.

The size of the digitizer work stage required that digitization be carried out in a segmented manner, using 10-second frames for a film transport speed of 1 cm/sec. Processed data for the first frame are covered in the preliminary report (Porter and others, 1979a) while the present report deals with the complete records. The reassembly procedure requires insertion of vertical butting lines approximately every 9 cm or 1.27 cm (0.5 in.) interior to the frame boundaries. The data traces (including the reference traces) and the time traces are digitized from a point at least 1.27 cm (0.5 in.) to the left of the left-hand butting line to a point at least the same distance to the right of the right-hand butting line, so that the 2.54 cm-wide (1.0 in.) overlap zone surrounding each butting line is completely digitized for all traces. After reassembly, trace portions exterior to the butting lines are removed.

Digitization

individual frames

↓

Reassembly of multiframe

accelerogram

1) superposition of butting lines
2) automatic computation and superposition of fiducials
3) smoothing with low-pass Hanning filter
4) decimation to reduce point density

↓

Editing and assembly of data for

1) minimum time spacing using 2nd order interpolation
2) time coordinate synchronization
3) reference trace selection
4) time trace selection

↓

Routine accelerogram processing

Phase I - Uncorrected accelerations
II - Corrected acccelerations, velocities and displacements
III - Response spectra
IV - Fourier amplitude spectra
V - Velocity response envelope spectra
Duration spectra of the velocity response envelopes

Figure 4. Functional block diagram of the four principal steps used in processing strong-motion records.

REASSEMBLY PROCEDURE

Accuracy of reassembly is based on the doubly digitized lines in the overlap zone line segments of the reference trace and the butting lines of each frame. Straight lines are then statistically fitted to these equal-length segments. This highly consistent approach produces a set of theoretically computed fiducials which are independent of the record signal activity and the film transport characteristics of any particular instrument. These fiducials are not only more accurate than those obtainable by other methods, they are automatic as well. The only operator intervention during the entire digitization-reassembly procedure takes place at the initiation of a line, and at points of digitizing ambiguity (i.e., trace crossings or mergings). The reassembly procedure consists of the following sequence of steps (Porter, and others, 1979b):

A. Single frame accelerogram

1) Calculation of the angle of inclination θ, positive if anticlockwise from the positive x-axis, for the line that is fitted by the theory of least squares to the reference trace,

2) Rotation of the data and time traces through the angle $(-\theta)$ to align the reference trace with the horizontal,

3) Translation of all time coordinates to make the onset zero for the left-most data trace.

B. First frame of a multiframe accelerogram

1) Calculation of the angle of inclination θ for that section of the reference trace to the left of the right-hand butting line,

2) Rotation of the data and time traces as well as the right-hand butting line through the angle $(-\theta)$, to align the above-mentioned portion of the reference trace with the horizontal,

3) Removal of the data exterior to, i.e., to the right of, the right-hand butting line,

4) Translation of all time coordinates to make the onset zero for the left-most data trace.

C. Intermediate and final frames of a multiframe accelerogram

1) Calculation of the angular difference β between the slope of the right-hand butting line in the preceeding frame and that for the left-hand butting line in the present frame,

2) Rotation of the data and time traces as well as the butting lines through the angle $(-\beta)$, to superimpose the above-mentioned butting lines,

3) Translation of all traces vertically, or parallel to the left-hand butting line, so that points of intersection of a relevant reference trace and butting line coincide.

4) Removal of the data exterior to the butting lines.

NUMERICAL FILTERING OF THE PRE-PROCESSED DATA

Raw data from the reassembly procedure are run through a low-pass filter, using an extension of the Hanning approach to act upon both time and amplitude coordinates for sets of three consecutive points (Brady, personal communication, 1979). The effective cut-off frequency for this preliminary filtering step is consequently much higher than the frequencies ultimately retained. The filtered data are then decimated by a factor of two to three by removing up to four points on any straight line section of trace. This preliminary filtering is not applied to operator inserted points, which are required, for example, where the point density is much less than usual. Two cycles through this sequence produce an output of approximately 100 points/second. The highest frequencies do not exceed 50 hertz after the second decimation.

EDITING AND ASSEMBLY OF THE PRE-PROCESSED DATA FILES

A file assembler prepares the pre-processed data for standarized accelerogram processing by editing and merging individual traces into a standard format file. The file assembler performs four editing steps. In the first, the monotonic (i.e., forward running) nature of the time coordinate is ensured by removing points reversed in time. Slight reversals in time are artifacts of line-following digitizers when they track large-amplitude signals with nearly vertical, running traces. In addition, points separated by 0.001 seconds or less are interpolated to a minimum spacing of 0.0011 seconds.

The second editing step pairs each data trace with its adjacent reference trace. On early triaxial instruments only one reference trace is available, but newer instruments provide one reference trace for each of the three data traces. In the case of central recorders, every two data traces are separated by a reference trace. Errors are minimized when each data trace is accompanied by its neighboring reference trace.

The third step of trace synchronization is needed for central recorder accelerograms because digitization is performed in horizontally running panels of one to four data traces each. The vertical reassembly of the record is accomplished by superimposing those reference trace intercepts with the first butting line which is common to more than one panel of digitizing.

A single time trace must be used for all central recorder data processing. This is required because the second time trace, if present, is generated by a separate relay with different time behavior. Examination of processed data shows that time cannot be interchanged without producing slight desynchronizations of the corrected data.

STANDARDIZED ACCELEROGRAM PROCESSING

The accelerograms are processed by applying the standardized programs to the pre-processed data. These programs were developed originally at the California Institute of Technology and subsequently extended by the USGS/SEB. The titles of these programs are:

Phase I	uncorrected accelerations
Phase II	corrected accelerations, velocities and displacements
Phase III	absolute acceleration spectra relative velocity spectra response spectra
Phase IV	Fourier amplitude spectra (both linear and logarithmic scales)
Phase V	velocity response envelope spectra duration spectra of the velocity response envelopes

VARIABLE SENSITIVITIES

A variable sensitivity modification is introduced in the Phase I program to accommodate the oblique-recording geometry of central recording systems. Post-earthquake calibration measurements are made for both central recorders to obtain the positive and negative 1g deflections (Table II, Freitas Building; Table III, North Hall).

This effect is taken into account through use of the following formulae (Figure 5):

$$B_R = \text{arc tan } (D/177800) + \tan A) - A \tag{1}$$

Where the acceleration in the positive direction is

$$a = (B_R \ / \ B+) \ g \tag{2}$$

and that for the negative direction is

$$a = (B_R \ / \ B-) \ g \tag{3}$$

The above quantities are defined as follows:

B_R = galvanometer deflection angle for an arbitrary acceleration a
D = trace deflection (micrometers)
A = galvanometer angle for zero signal
B+ = galvanometer deflection angle for + 1g acceleration
B– = galvanometer deflection angle for – 1g acceleration
a = acceleration (g)

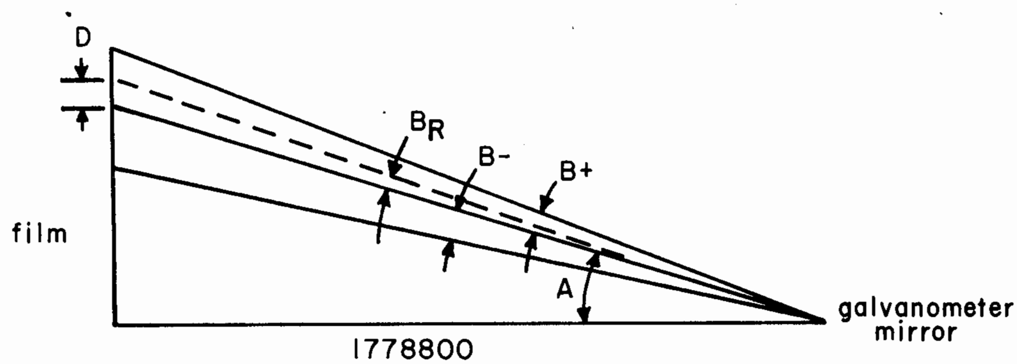


Figure 5. Oblique-angle geometry of the central recorder

SELECTION OF NUMERICAL FILTERS

Numerical filters used in the corrected data calculation (Phase II) are selected on the basis of shortest record involved. The low-pass filter settings $f_c = 0.5$ Hz = and $df_1 = 0.30$ Hz are determined in accordance with findings of Basili and Brady (1978).

VALIDATION PROCEDURES

Validation procedures are carried out for each step to ensure the quality of the data. Digitization is verified by overlaying plots of the reassembled accelerograms on the original film records. Consistency of digitization is examined by processing a doubly digitized trace (Table I).

Table I

Reproducibility and Consistency of the Digitizing Process
Comparison of Values for a Doubly Digitized Trace
Peak Values (N Hall Trace 8 frame I)

Data set	Uncorrected acceleration (g)	Corrected acceleration (cm/sec^2)	Corrected velocity (cm/sec^2)	Corrected displacement (cm)
N Hall 5678	0.5922	-551.1	-47.3	6.04
N Hall 89	0.5892	-543.7	-47.2	6.05

The validity and consistency of the reassembly procedure is determined by the data's conformity to the following criteria:

1) nearly zero slopes of the reference traces for the first frame after rotation to align them horizontally (ensuring consistent horizontal orientation of the first frame of each digitizing sequence);
2) close agreement in the slopes of the butting lines after rotation to superimpose them (ensuring proper angular orientation of the frames);
3) close agreement in the slopes of the overlap zone line segments for the two frames as seen by the two frames associated with each butting line (ensuring trace continuity across each butting line);
4) similar changes in reference trace slopes as they cross a particular butting line (ensuring consistency in microrotations of film as it advances through central recorders);
5) close agreement in time coordinates for intercepts between data traces and butting line, as computed in the two frames associated with each butting line (ensuring continuity of traces across butting lines);
6) orientation of the butting line data trace intercepts in accordance with each butting line slope (ensuring use of the proper equations for the butting lines);
7) orientation of the extremities of the overlap zone line segments in accordance with the butting line slope (ensuring the correct construction of the overlap zones);
8) orientation of the extremities of the data traces for each frame in accordance with the butting line slope (ensuring correct removal of the data exterior to the butting lines).

The above quality control criteria were used to evaluate the reassembly process carried out on the records under investigaiton. It was found that differences between slopes between any pair of mathematically superimposed lines do not exceed 10^{-5} and generally are in the range 10^{-6} to 10^{-7}. Further, differences in intercepts between data traces and butting lines on adjacent frames do not exceed 0.6 micrometer in the time direction and generally are in the range 0.01 - 0.04 micrometer. Since one micrometer on the record is equivalent to 10^{-4} second, these differences are at the microsecond level and so are negligible.

The use of the Hanning filter to smooth the pre-processed data was found to have an effect of less than 1% on peak amplitudes of corrected accelerations. No appreciable effects were observed for the corrected velocities or displacements.

The numerical filters used in computing corrected data (Phase II) are verified by making certain that all records satisfy the duration criteria of Basili and Brady (1978). The data under study were also examined for undesirable effects. No long-term noise was observed, and displacements did not exhibit excessive oscillations.

CONTENTS

PART II

UCSB GOLETA (FREEFIELD)

The UCSB Goleta free-field station consists of a single, triaxial analog recording accelerograph attached to the floor slab of the University of California maintenance shop building. The station, located at 34.42° N and 119.86° W, is 14.02 km from the epicenter at an epicenter-station aximuth of 293.35°. The building was undamaged.

Recorder information, UCSB Goleta

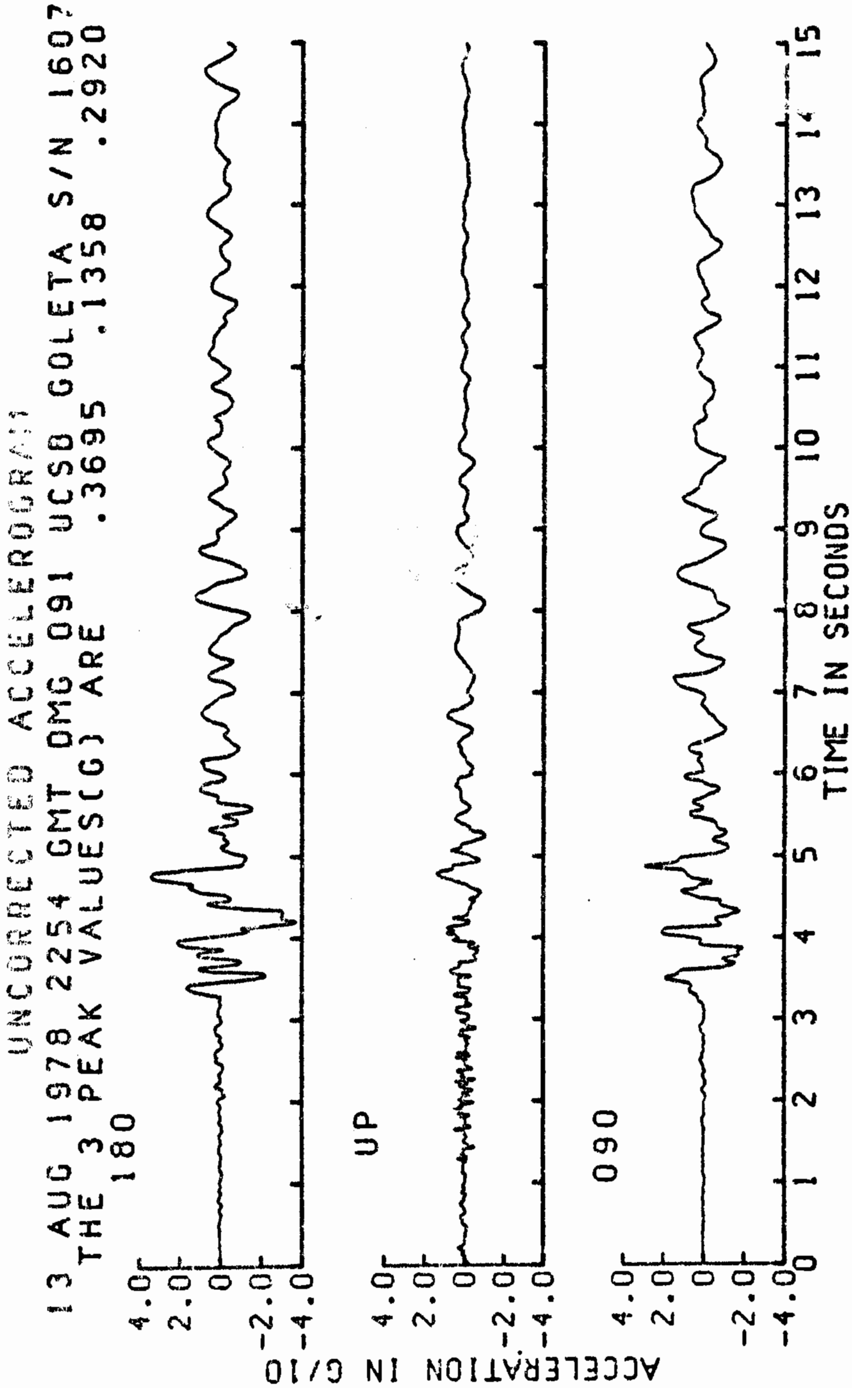
Instrument type: Kinemetrics SMA-1
Serial number 1607

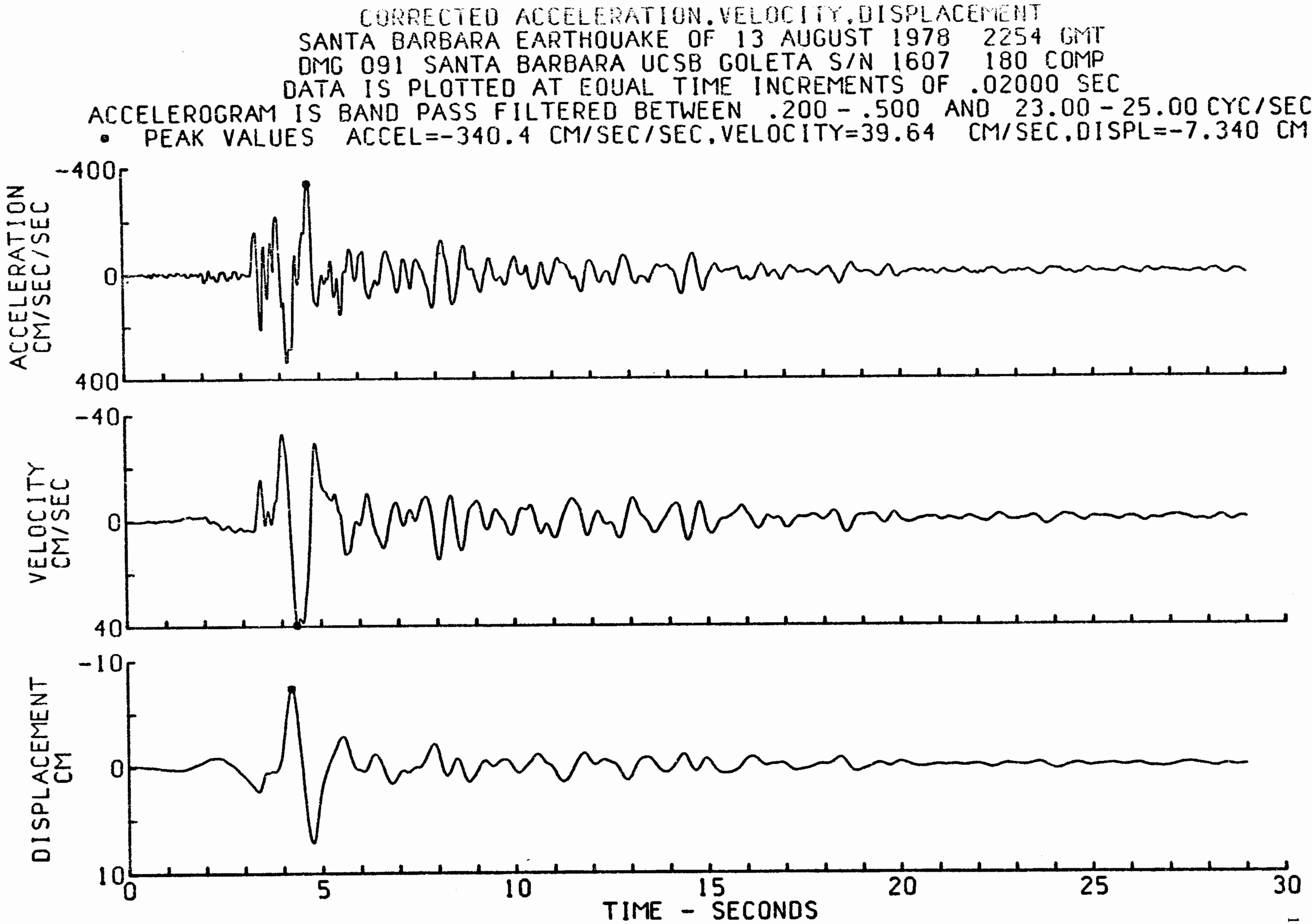
Film installed: 11 April 1978 Recovered: 14 August 1978

Trace	Component	Sensitivity (mm/g)	Period (sec)	Crit. Damp. %
180*	L	18.1	.03846	59.1
up	V	18.4	.03891	60.2
90*	T	18.9	.03937	55.2

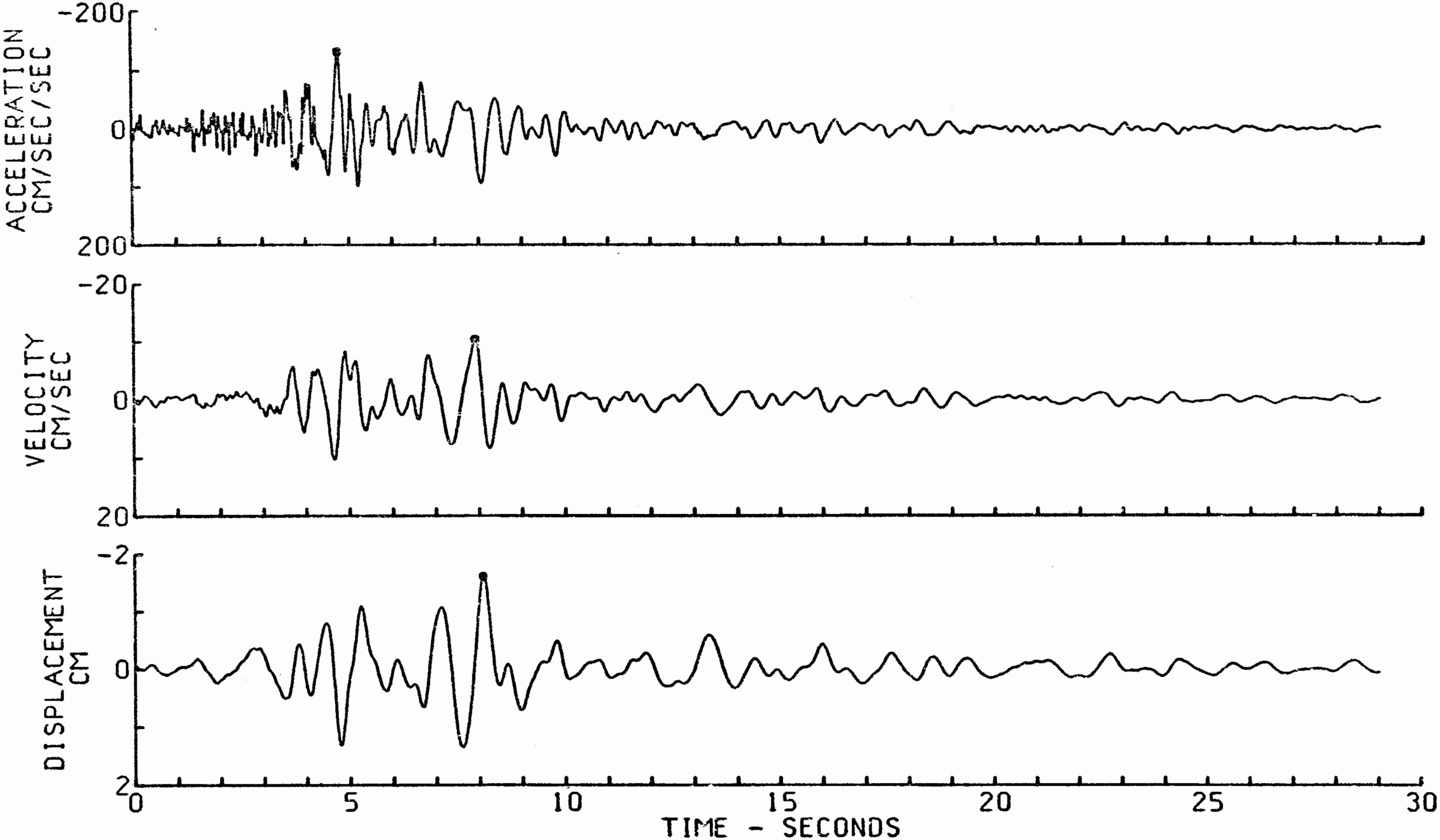
*Azimuth

The digitized uncorrected accelerograms, corrected acceleration, velocity, displacement plots and spectra are shown on pages 14 through 38 .

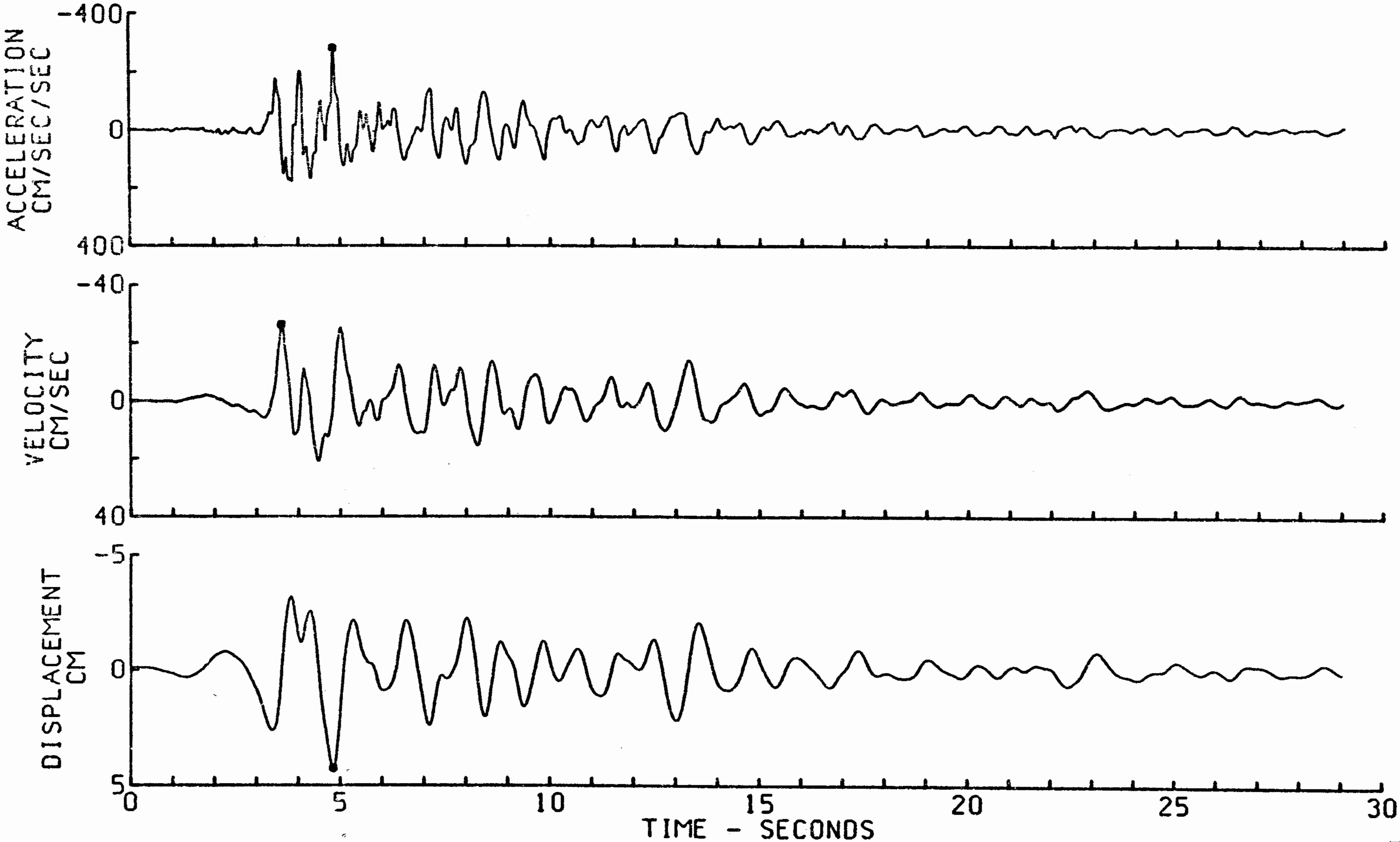

UNCORRECTED ACCELEROGRAM
13 AUG 1978 2254 GMT DMG 091 UCSB GOLETA S/N 1607
THE 3 PEAK VALUES(G) ARE .3695 .1358 .2920
180
UP
090
TIME IN SECONDS
ACCELERATION IN G/10

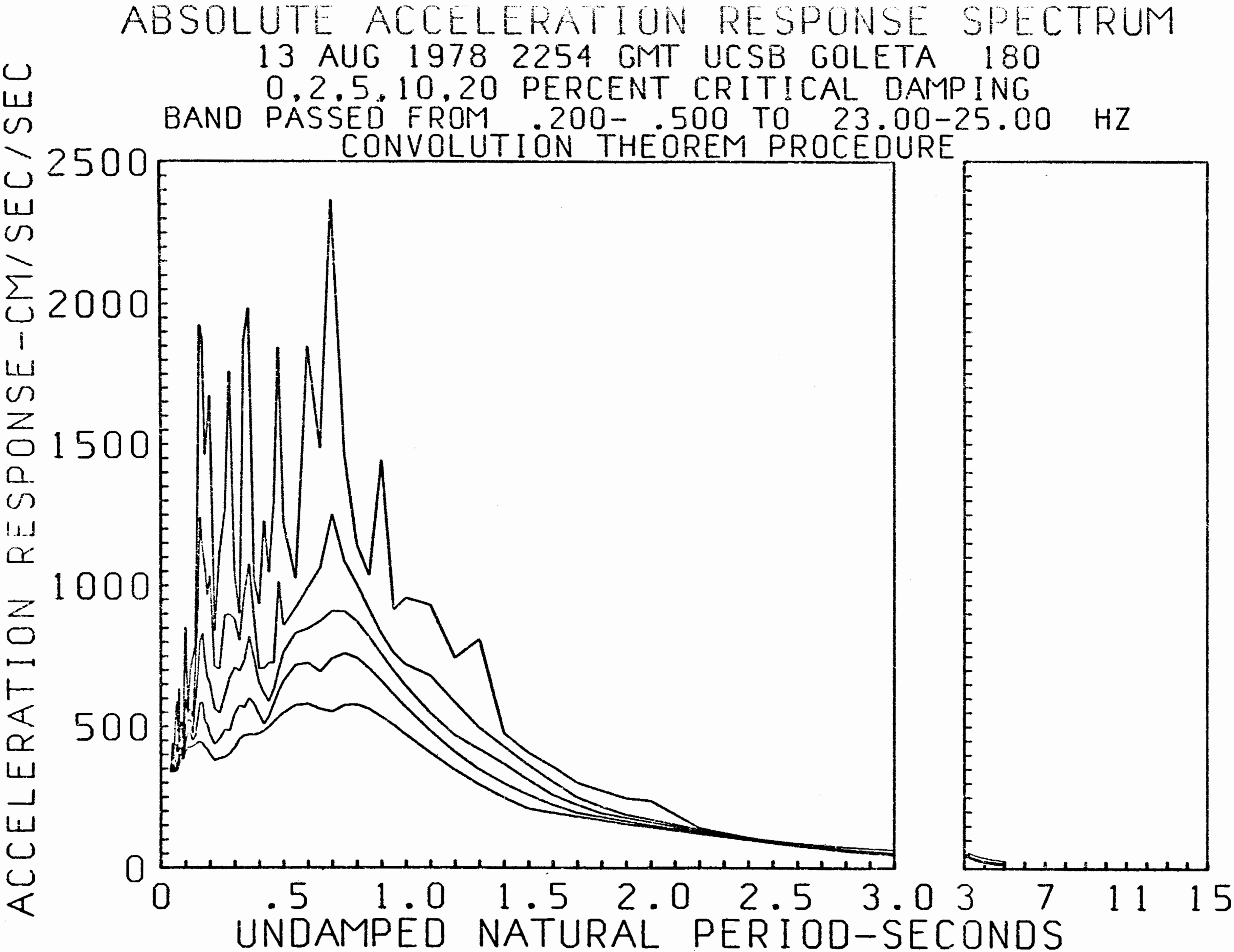

CORRECTED ACCELERATION, VELOCITY, DISPLACEMENT
SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978 2254 GMT
DMG 091 SANTA BARBARA UCSB GOLETA S/N 1607 180 COMP
DATA IS PLOTTED AT EQUAL TIME INCREMENTS OF .02000 SEC
ACCELEROGRAM IS BAND PASS FILTERED BETWEEN .200 - .500 AND 23.00 - 25.00 CYC/SEC
• PEAK VALUES ACCEL=-340.4 CM/SEC/SEC, VELOCITY=39.64 CM/SEC, DISPL=-7.340 CM
ACCELERATION CM/SEC/SEC
-400
0
400
VELOCITY CM/SEC
-40
0
40
DISPLACEMENT CM
-10
0
10
0
5
10
15
20
25
30
TIME - SECONDS

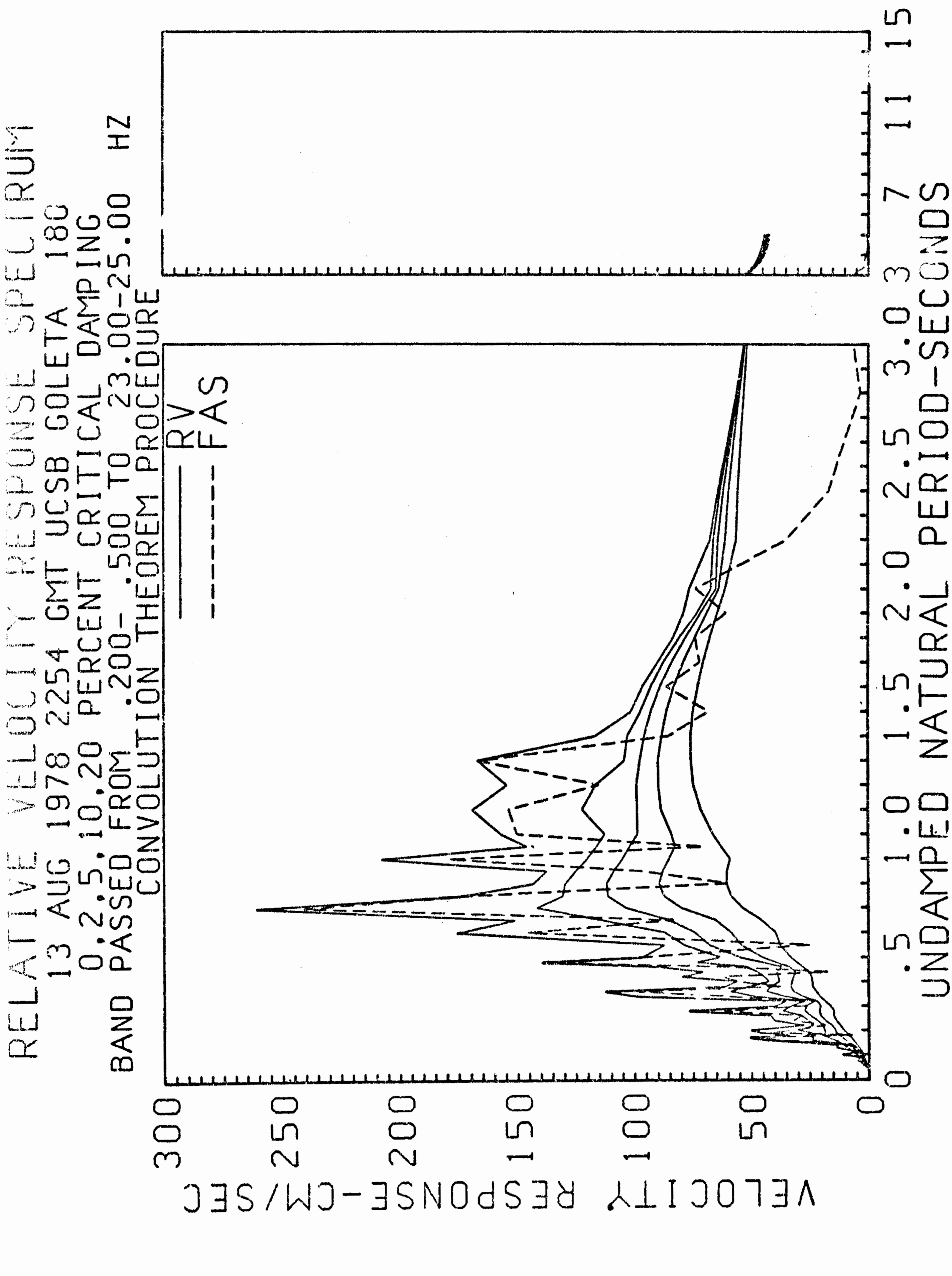
CORRECTED ACCELERATION,VELOCITY,DISPLACEMENT
SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978 2254 GMT
DMG 091 SANTA BARBARA UCSB GOLETA S/N 1607 UP COMP
DATA IS PLOTTED AT EQUAL TIME INCREMENTS OF .02000 SEC
ACCELEROGRAM IS BAND PASS FILTERED BETWEEN .200 - .500 AND 23.00 - 25.00 CYC/SEC
• PEAK VALUES ACCEL=-132.7 CM/SEC/SEC,VELOCITY=-10.43 CM/SEC,DISPL=-1.600 CM

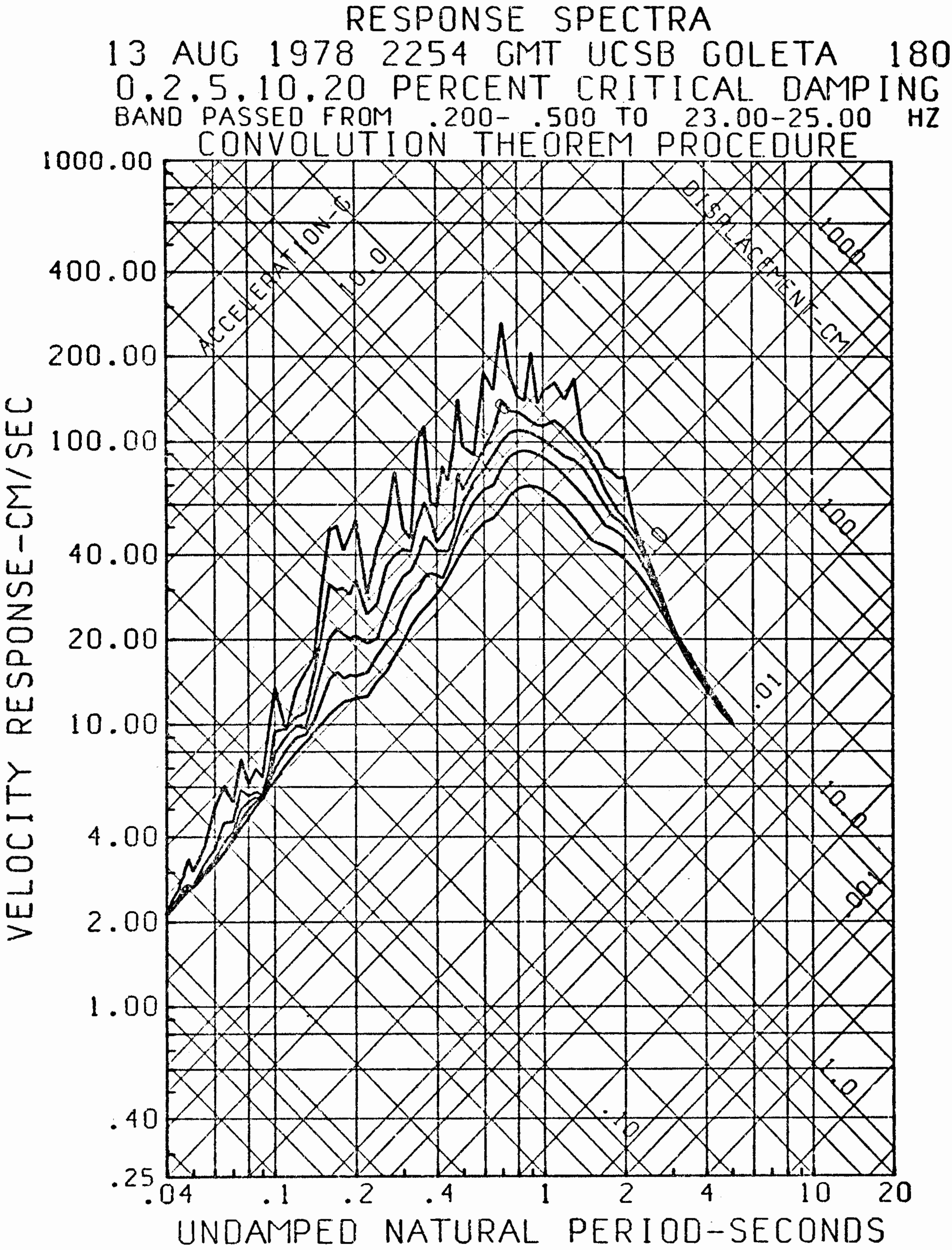


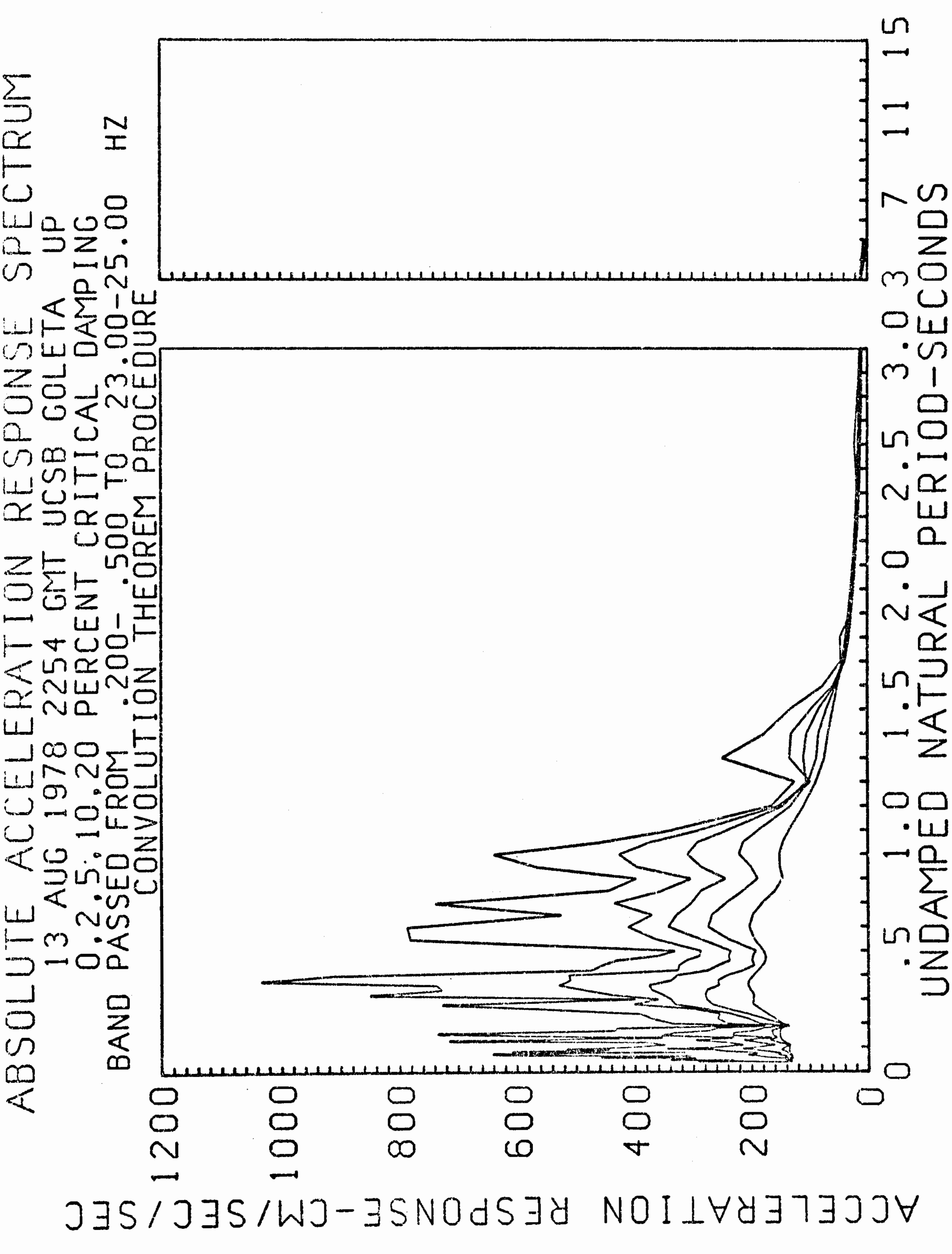
CORRECTED ACCELERATION, VELOCITY, DISPLACEMENT
SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978 2254 GMT
DMG 091 SANTA BARBARA UCSB GOLETA S/N 1607 090 COMP
DATA IS PLOTTED AT EQUAL TIME INCREMENTS OF .02000 SEC
ACCELEROGRAM IS BAND PASS FILTERED BETWEEN .200 - .500 AND 23.00 - 25.00 CYC/SEC
• PEAK VALUES ACCEL=-282.8 CM/SEC/SEC, VELOCITY=-26.08 CM/SEC, DISPL=4.250 CM

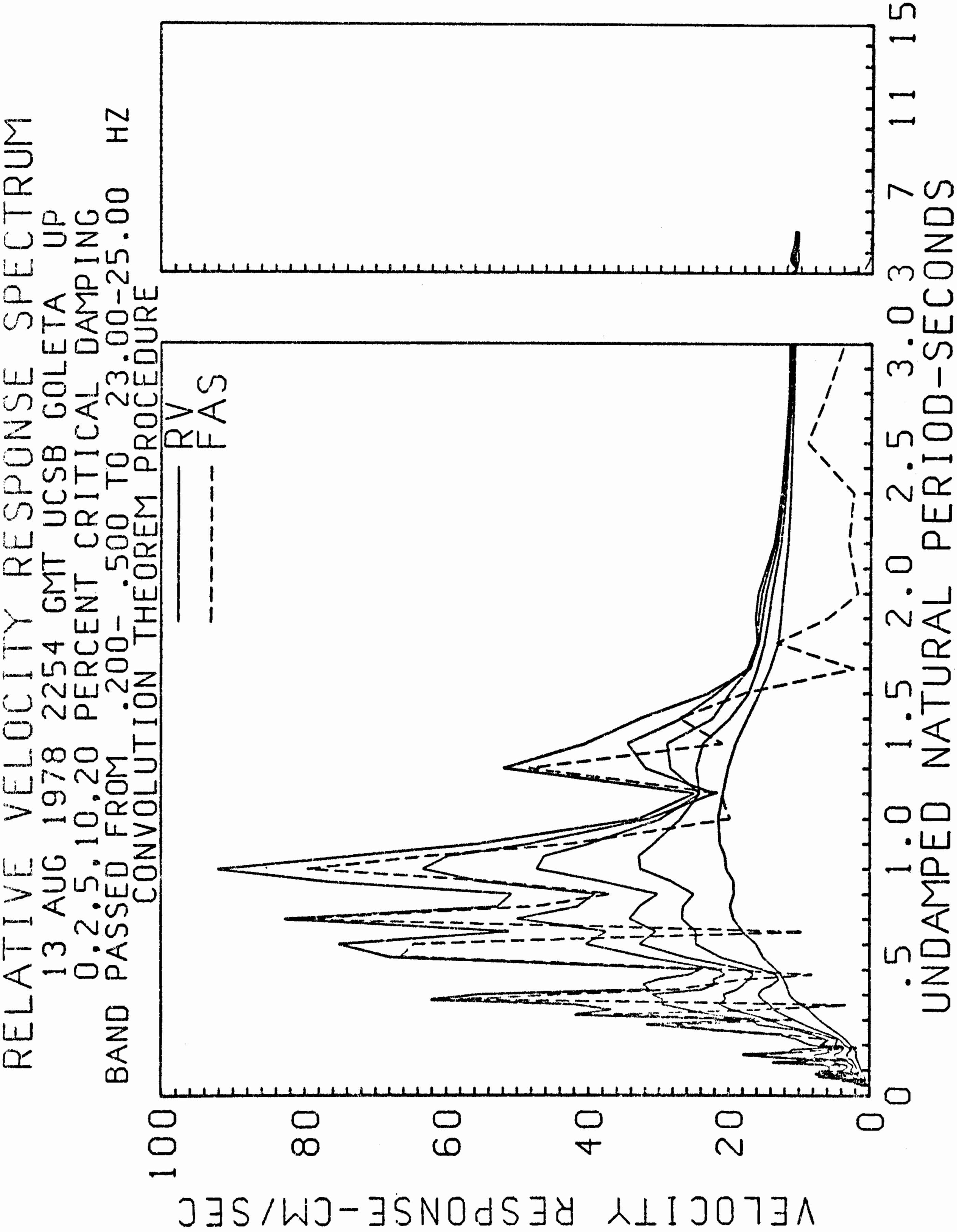


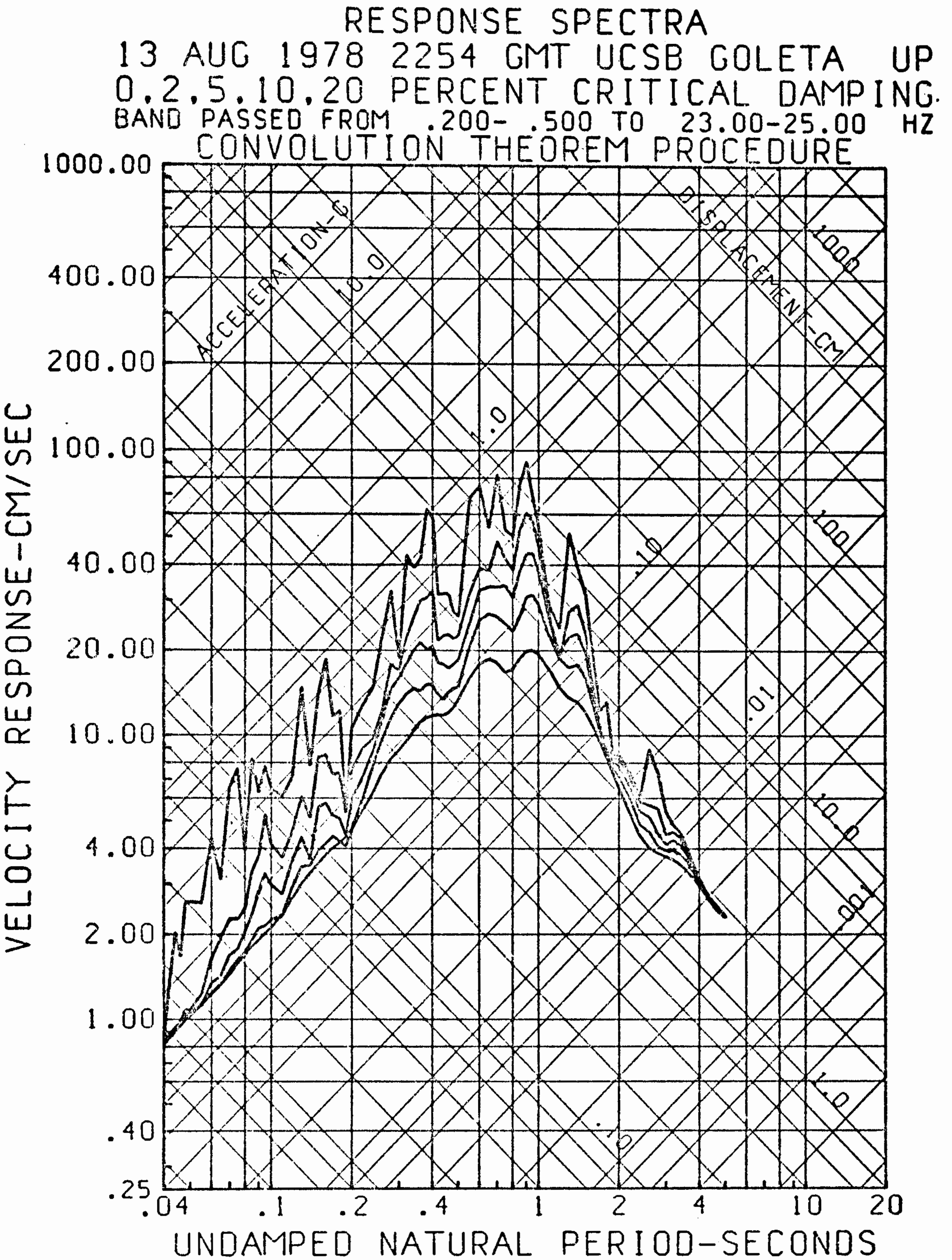

ABSOLUTE ACCELERATION RESPONSE SPECTRUM
13 AUG 1978 2254 GMT UCSB GOLETA 180
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
CONVOLUTION THEOREM PROCEDURE
ACCELERATION RESPONSE-CM/SEC/SEC
2500
2000
1500
1000
500
0
0
.5
1.0
1.5
2.0
2.5
3.0
3
7
11
15
UNDAMPED NATURAL PERIOD-SECONDS

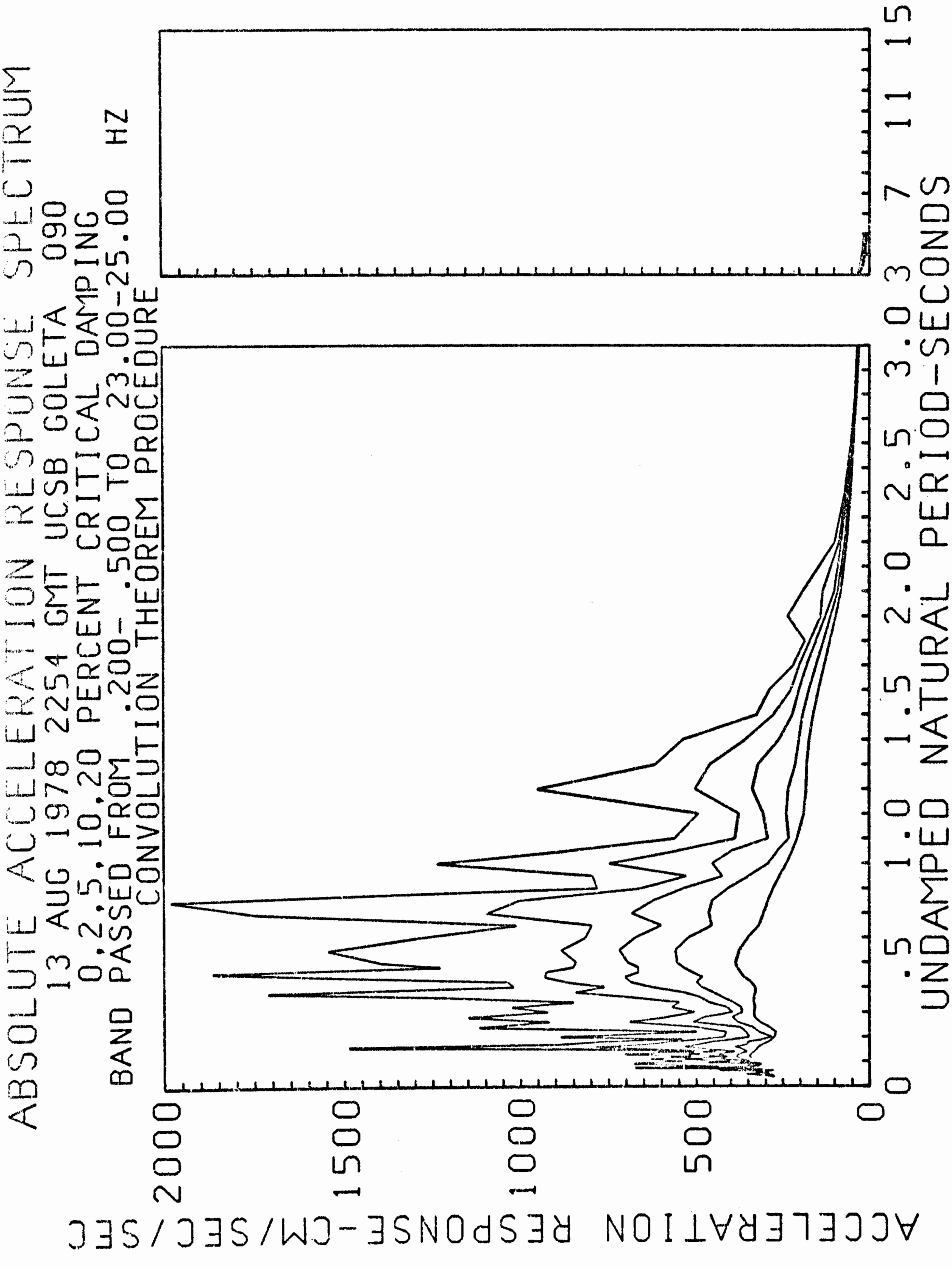

RELATIVE VELOCITY RESPONSE SPECTRUM
13 AUG 1978 2254 GMT UCSB GOLETA 180
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
CONVOLUTION THEOREM PROCEDURE
RV
FAS
0
.5
1.0
1.5
2.0
2.5
3.0
3
7
11
15
UNDAMPED NATURAL PERIOD-SECONDS
0
50
100
150
200
250
300
VELOCITY RESPONSE-CM/SEC

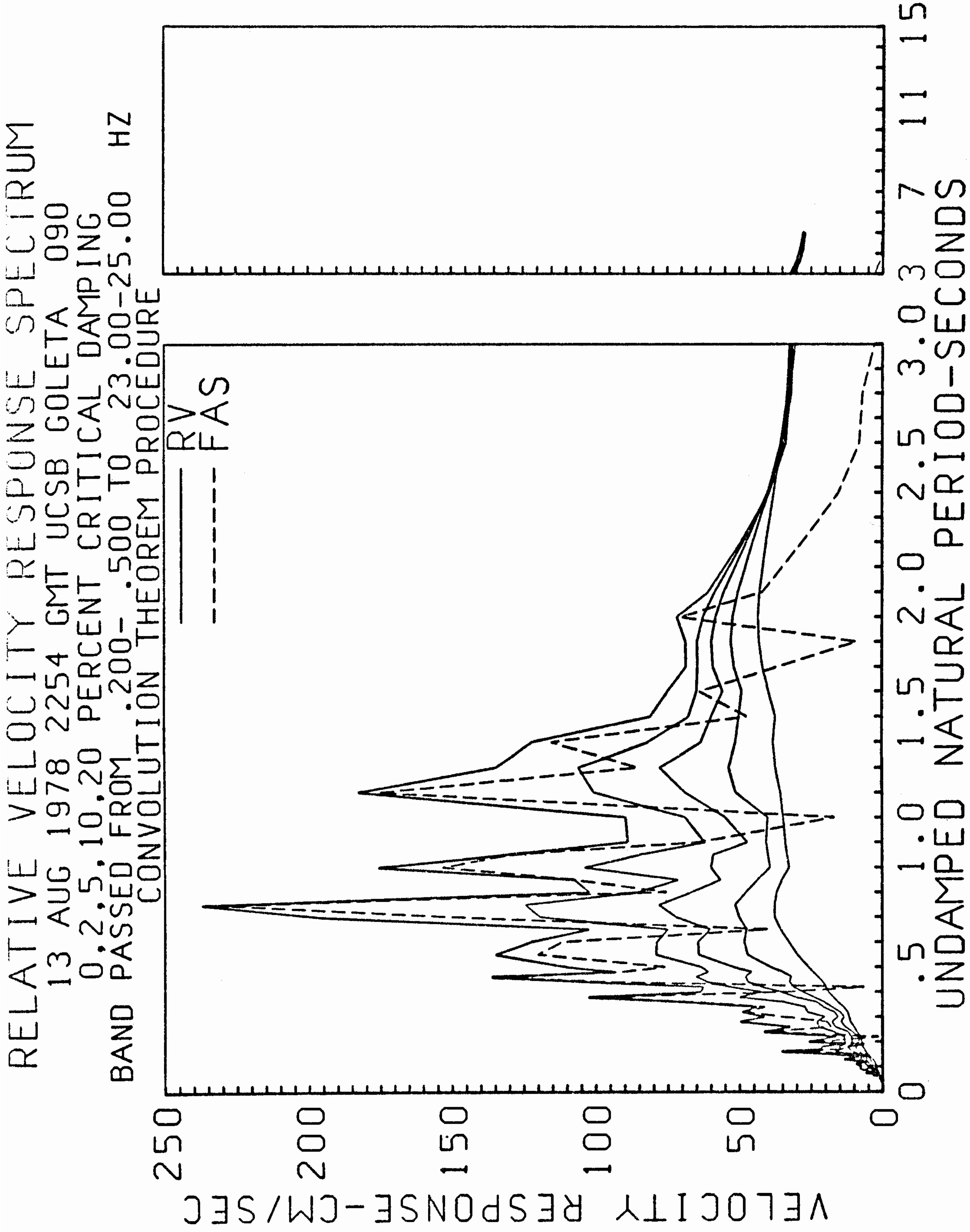

RESPONSE SPECTRA
13 AUG 1978 2254 GMT UCSB GOLETA 180
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
CONVOLUTION THEOREM PROCEDURE
ACCELERATION-G
10.0
DISPLACEMENT-CM
1000
100
.01
10.0
.001
1.0
.10
VELOCITY RESPONSE-CM/SEC
1000.00
400.00
200.00
100.00
40.00
20.00
10.00
4.00
2.00
1.00
.40
.25
.04
.1
.2
.4
1
2
4
10
20
UNDAMPED NATURAL PERIOD-SECONDS

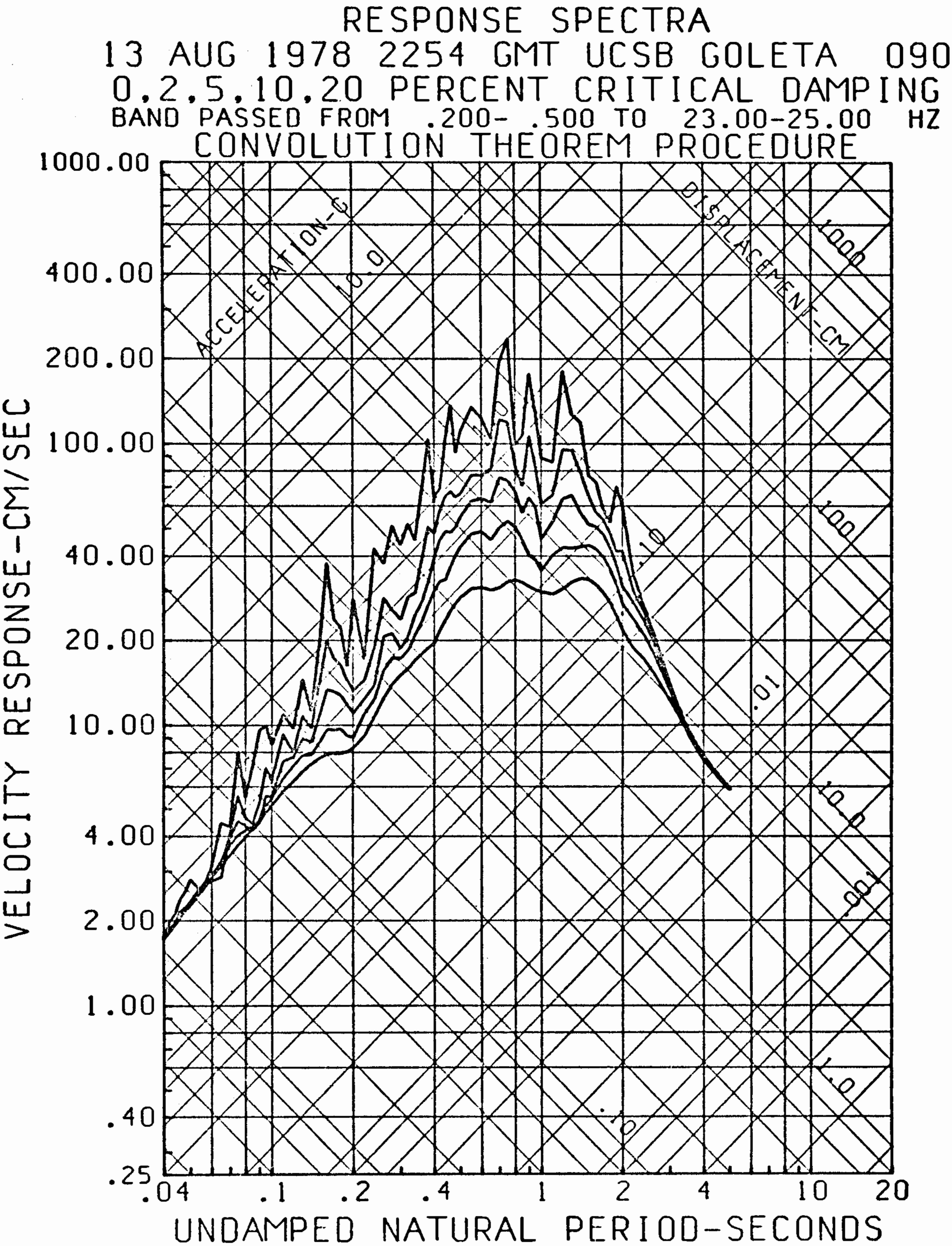

ABSOLUTE ACCELERATION RESPONSE SPECTRUM
13 AUG 1978 2254 GMT UCSB GOLETA UP
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
CONVOLUTION THEOREM PROCEDURE
0 .5 1.0 1.5 2.0 2.5 3.0 3 7 11 15
UNDAMPED NATURAL PERIOD-SECONDS
0 200 400 600 800 1000 1200
ACCELERATION RESPONSE-CM/SEC/SEC

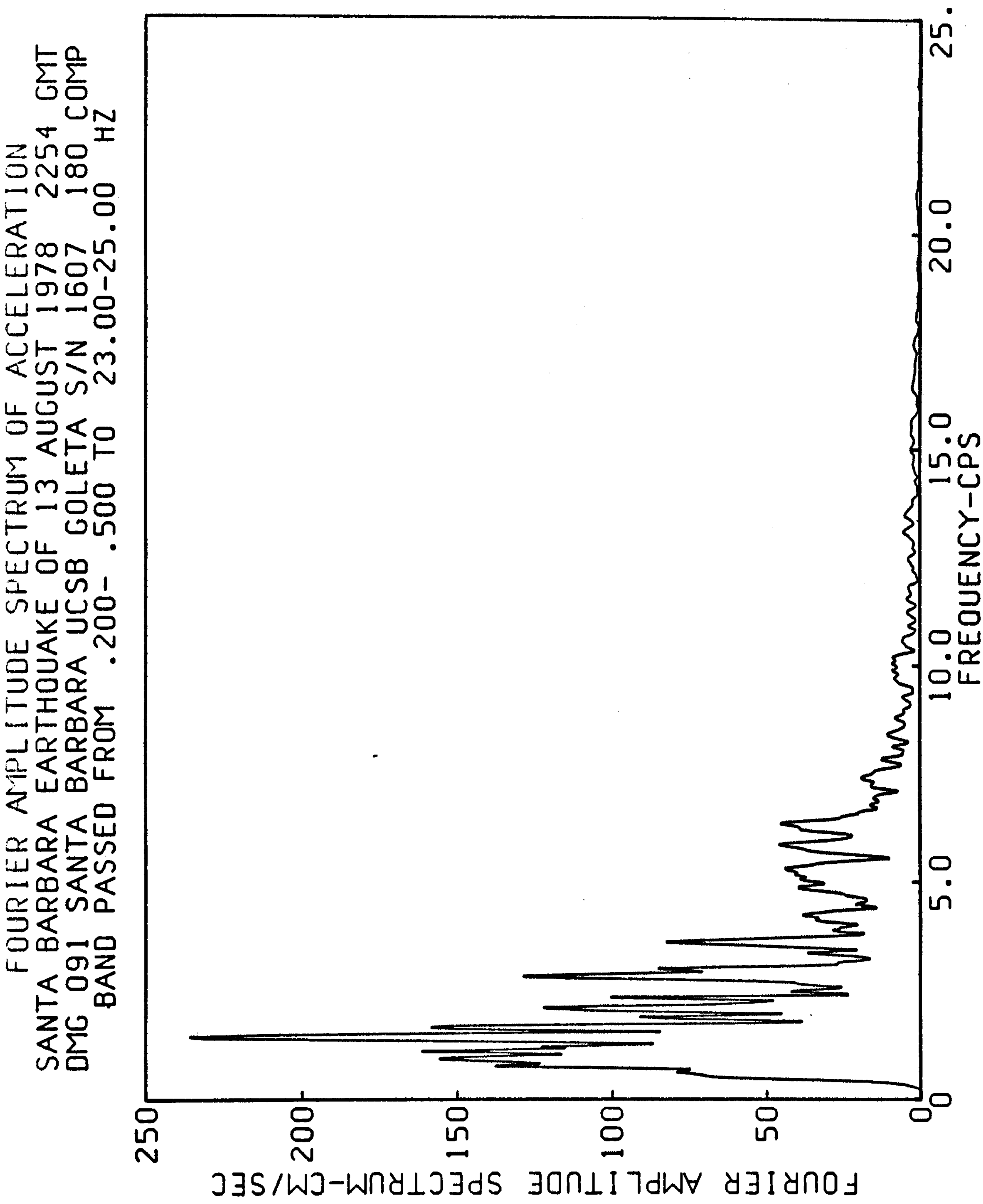

RELATIVE VELOCITY RESPONSE SPECTRUM
13 AUG 1978 2254 GMT UCSB GOLETA UP
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
CONVOLUTION THEOREM PROCEDURE
RV
FAS
VELOCITY RESPONSE-CM/SEC
100
80
60
40
20
0
0
.5
1.0
1.5
2.0
2.5
3.0
3
7
11
15
UNDAMPED NATURAL PERIOD-SECONDS

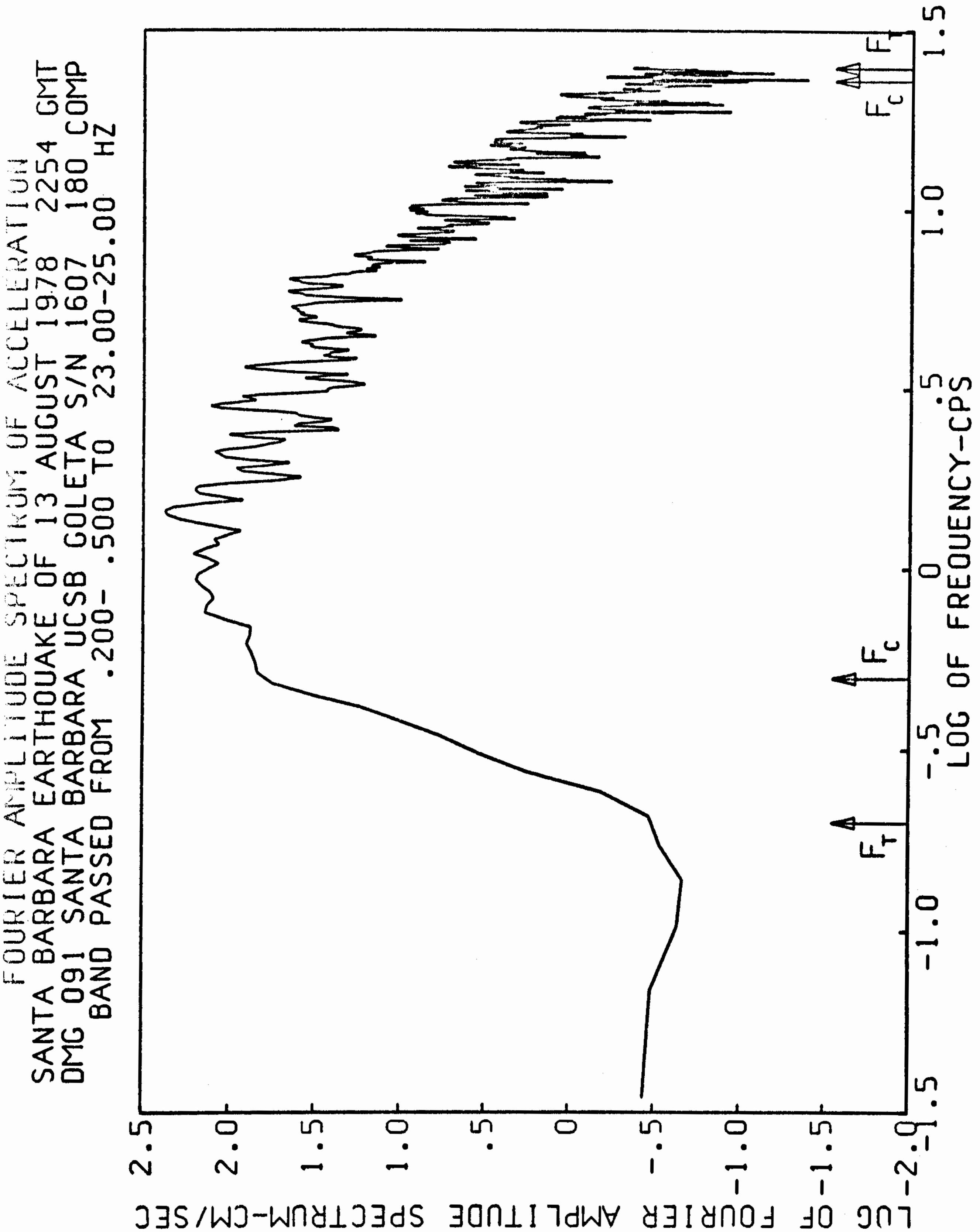

RESPONSE SPECTRA
13 AUG 1978 2254 GMT UCSB GOLETA UP
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
CONVOLUTION THEOREM PROCEDURE
VELOCITY RESPONSE-CM/SEC
UNDAMPED NATURAL PERIOD-SECONDS
ACCELERATION-G
DISPLACEMENT-CM
1000.00
400.00
200.00
100.00
40.00
20.00
10.00
4.00
2.00
1.00
.40
.25
.04
.1
.2
.4
1
2
4
10
20

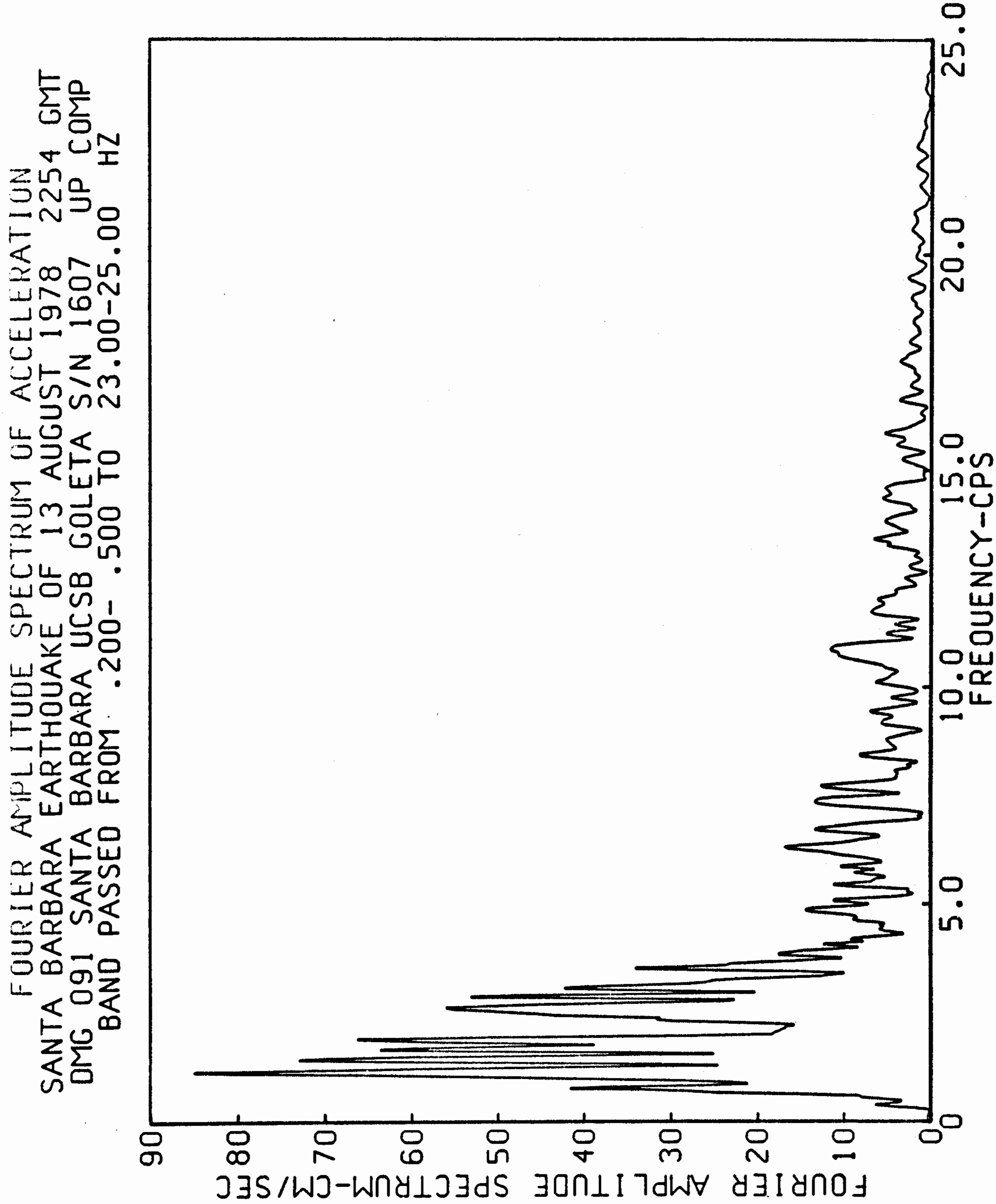

ABSOLUTE ACCELERATION RESPONSE SPECTRUM
13 AUG 1978 2254 GMT UCSB GOLETA 090
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
CONVOLUTION THEOREM PROCEDURE
0
.5
1.0
1.5
2.0
2.5
3.0
3
7
11
15
UNDAMPED NATURAL PERIOD-SECONDS
2000
1500
1000
500
0
ACCELERATION RESPONSE-CM/SEC/SEC

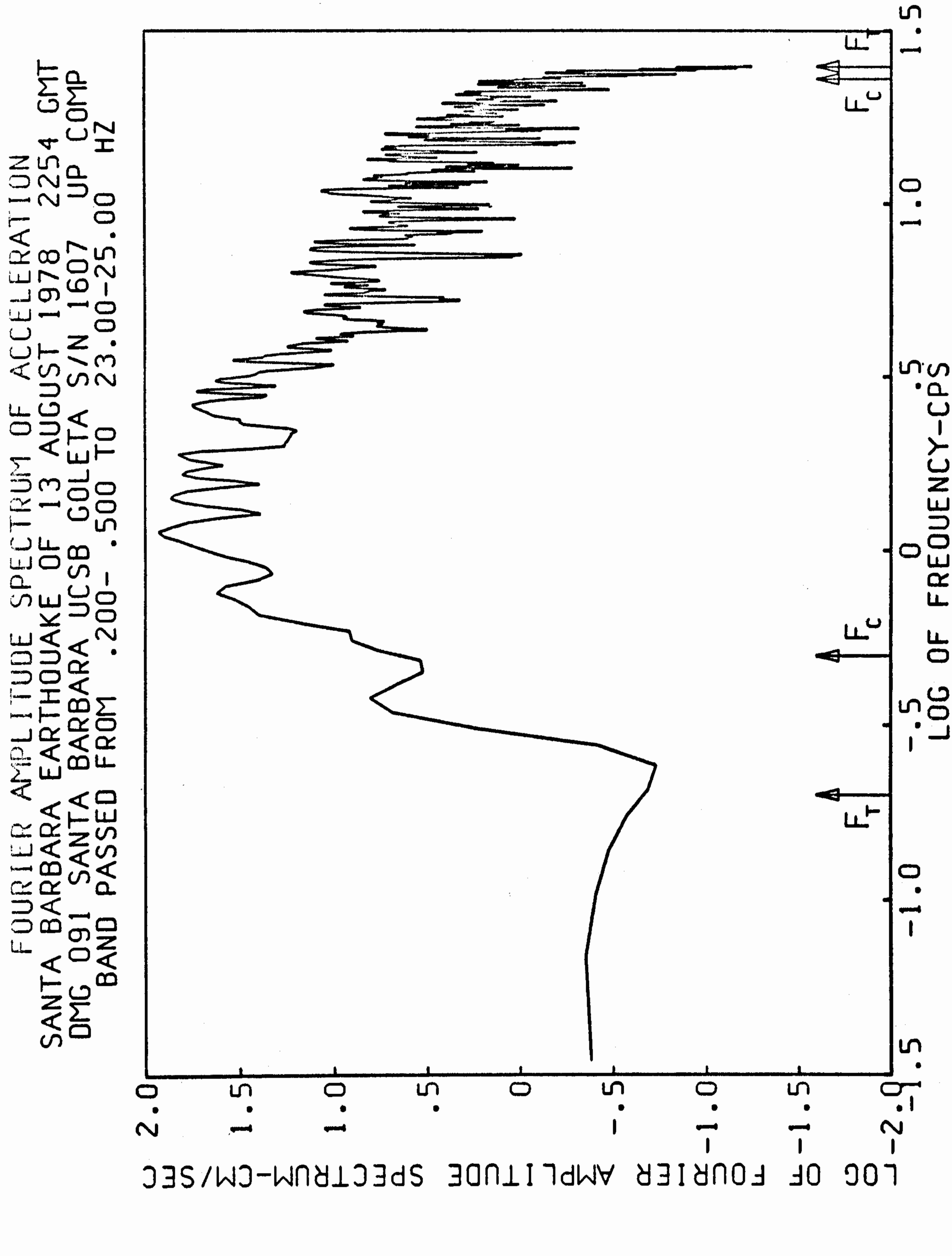

RELATIVE VELOCITY RESPONSE SPECTRUM
13 AUG 1978 2254 GMT UCSB GOLETA 090
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
CONVOLUTION THEOREM PROCEDURE
RV
FAS
0
.5
1.0
1.5
2.0
2.5
3.0
3
7
11
15
UNDAMPED NATURAL PERIOD-SECONDS
0
50
100
150
200
250
VELOCITY RESPONSE-CM/SEC

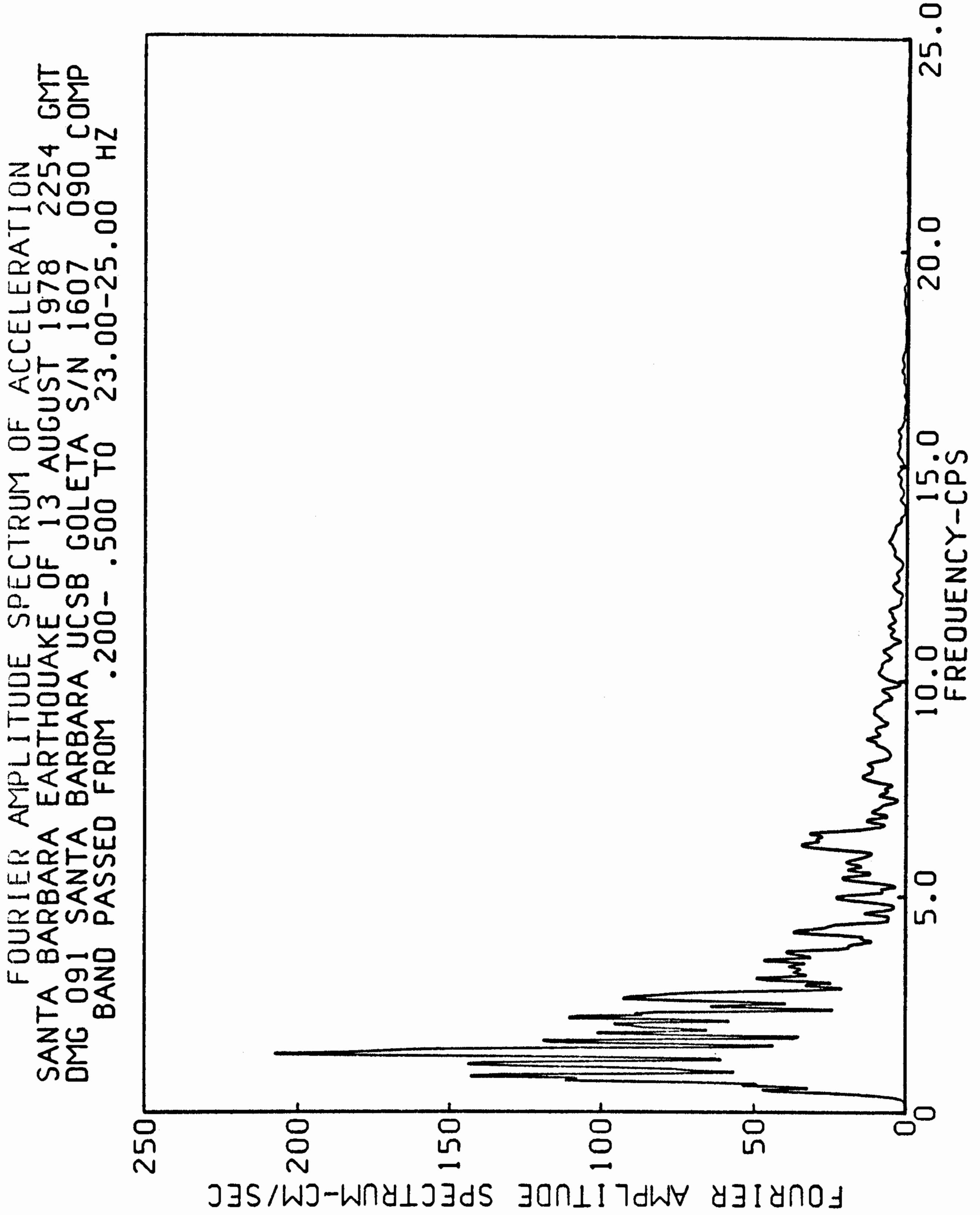

RESPONSE SPECTRA
13 AUG 1978 2254 GMT UCSB GOLETA 090
0,2,5,10,20 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
CONVOLUTION THEOREM PROCEDURE
VELOCITY RESPONSE-CM/SEC
1000.00
400.00
200.00
100.00
40.00
20.00
10.00
4.00
2.00
1.00
.40
.25
ACCELERATION-G
10.0
DISPLACEMENT-CM
1000
100
.10
.01
10.0
.001
1.0
.10
.04
.1
.2
.4
1
2
4
10
20
UNDAMPED NATURAL PERIOD-SECONDS

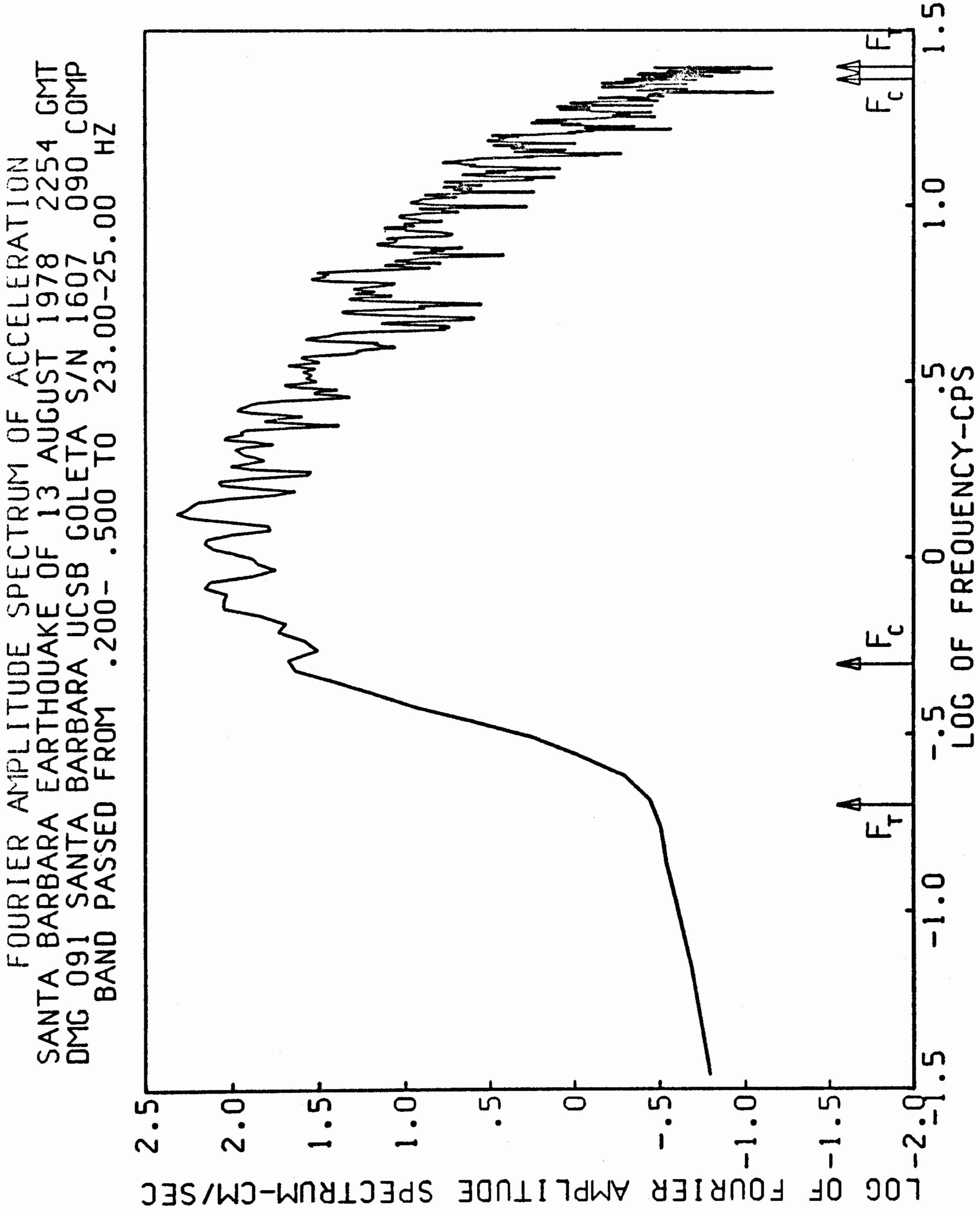

FOURIER AMPLITUDE SPECTRUM OF ACCELERATION
SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978 2254 GMT
DMG 091 SANTA BARBARA UCSB GOLETA S/N 1607 180 COMP
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
FOURIER AMPLITUDE SPECTRUM-CM/SEC
FREQUENCY-CPS
0
50
100
150
200
250
5.0
10.0
15.0
20.0
25.0

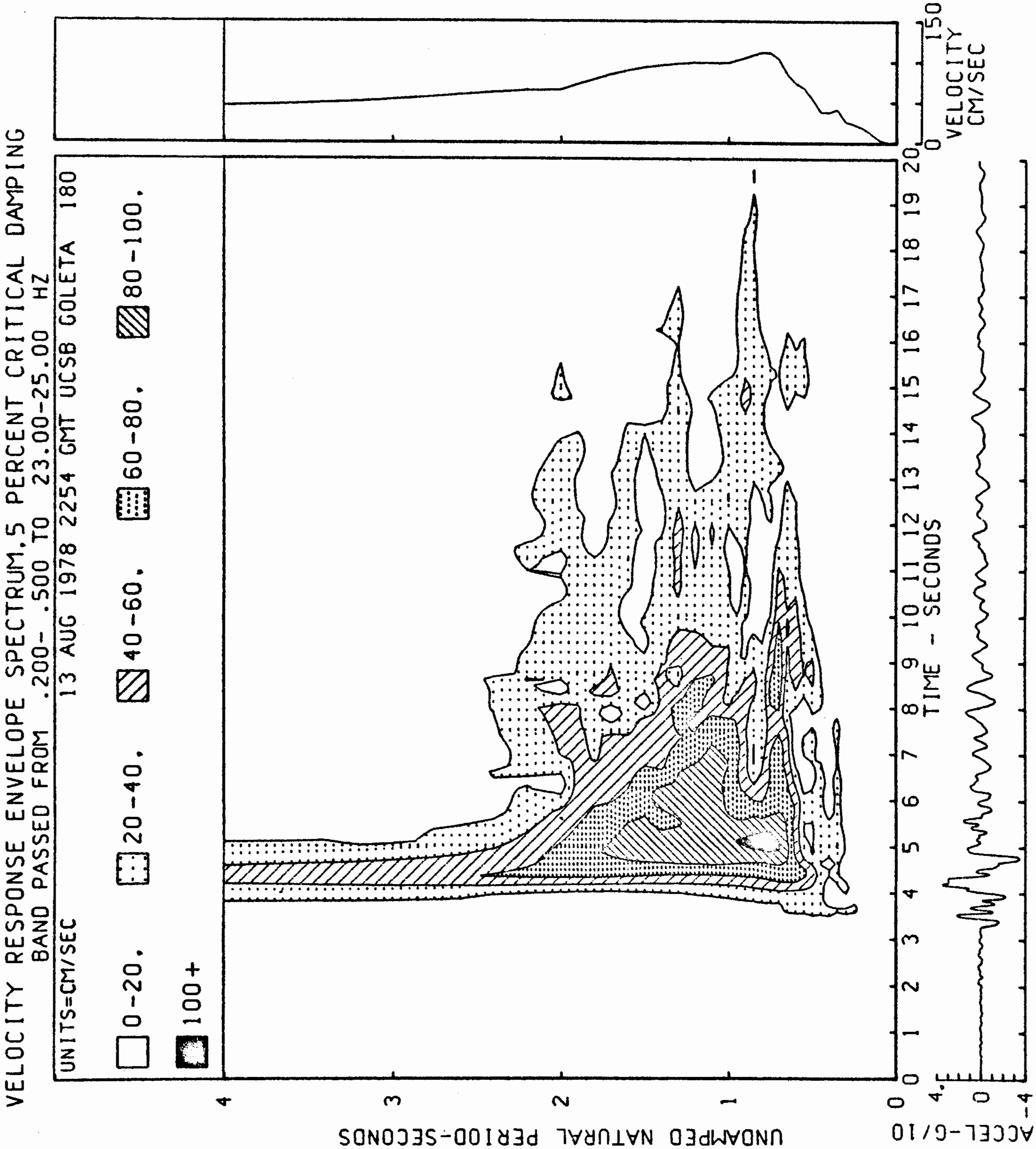

FOURIER AMPLITUDE SPECTRUM OF ACCELERATION
SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978 2254 GMT
DMG 091 SANTA BARBARA UCSB GOLETA S/N 1607 180 COMP
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
LOG OF FREQUENCY-CPS
LOG OF FOURIER AMPLITUDE SPECTRUM-CM/SEC
F_T
F_C

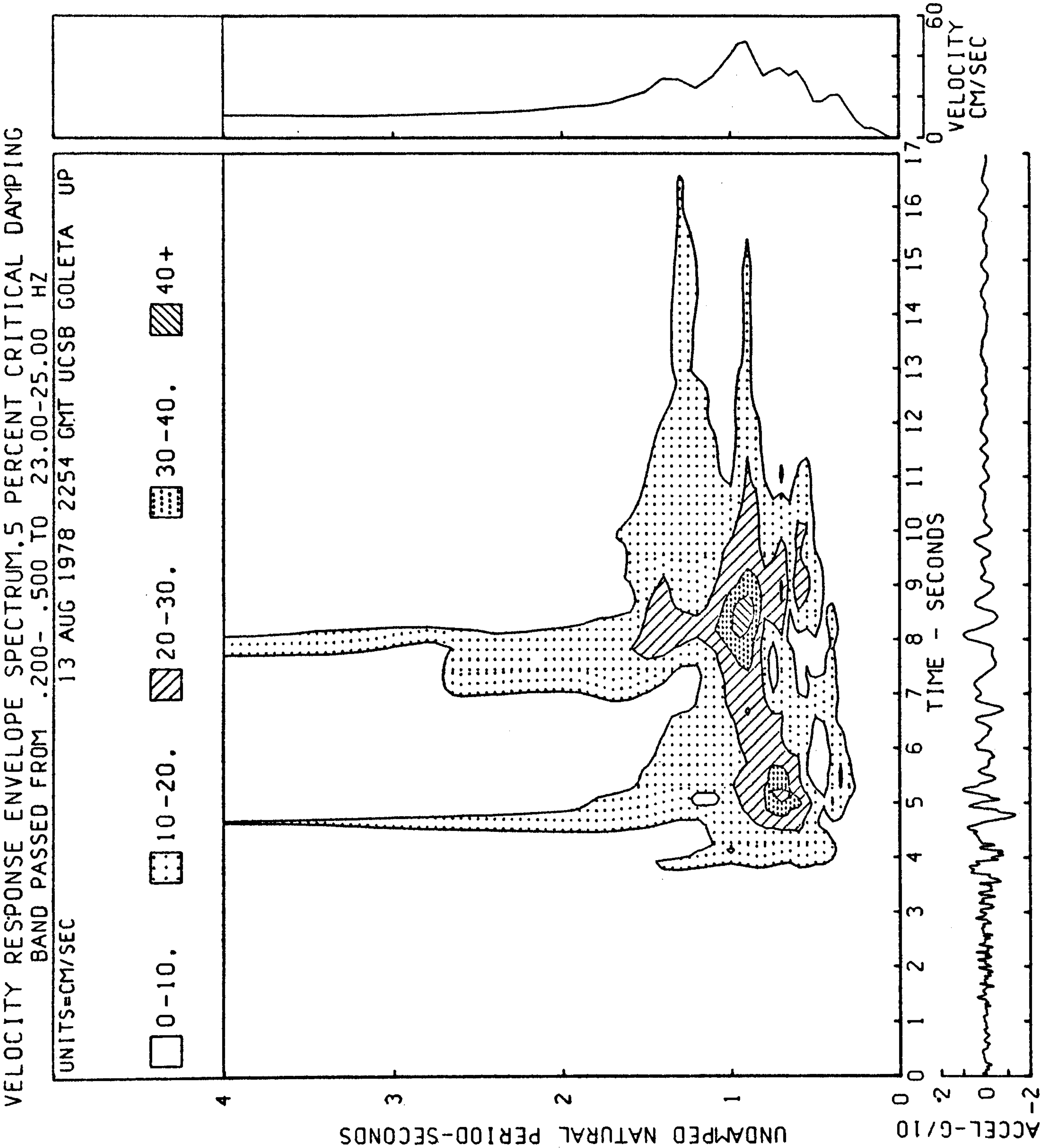

FOURIER AMPLITUDE SPECTRUM OF ACCELERATION
SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978 2254 GMT
DMG 091 SANTA BARBARA UCSB GOLETA S/N 1607 UP COMP
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
FOURIER AMPLITUDE SPECTRUM-CM/SEC
0
10
20
30
40
50
60
70
80
90
5.0
10.0
15.0
20.0
25.0
FREQUENCY-CPS

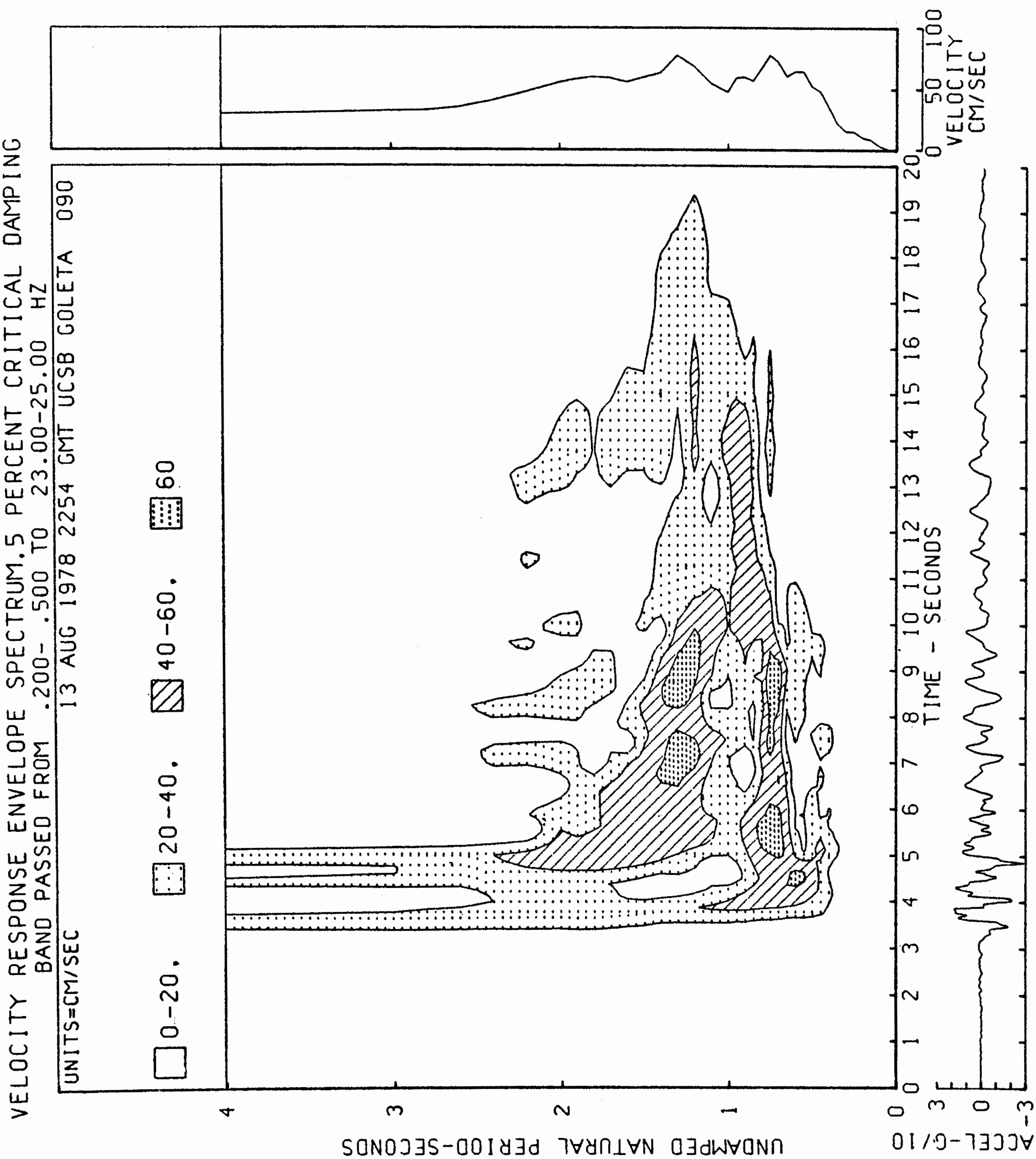

FOURIER AMPLITUDE SPECTRUM OF ACCELERATION
SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978 2254 GMT
DMG 091 SANTA BARBARA UCSB GOLETA S/N 1607 UP COMP
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
LOG OF FREQUENCY-CPS
LOG OF FOURIER AMPLITUDE SPECTRUM-CM/SEC
F T
F C
F C
F T


FOURIER AMPLITUDE SPECTRUM OF ACCELERATION
SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978 2254 GMT
DMG 091 SANTA BARBARA UCSB GOLETA S/N 1607 090 COMP
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
FREQUENCY-CPS
0
5.0
10.0
15.0
20.0
25.0
FOURIER AMPLITUDE SPECTRUM-CM/SEC
0
50
100
150
200
250

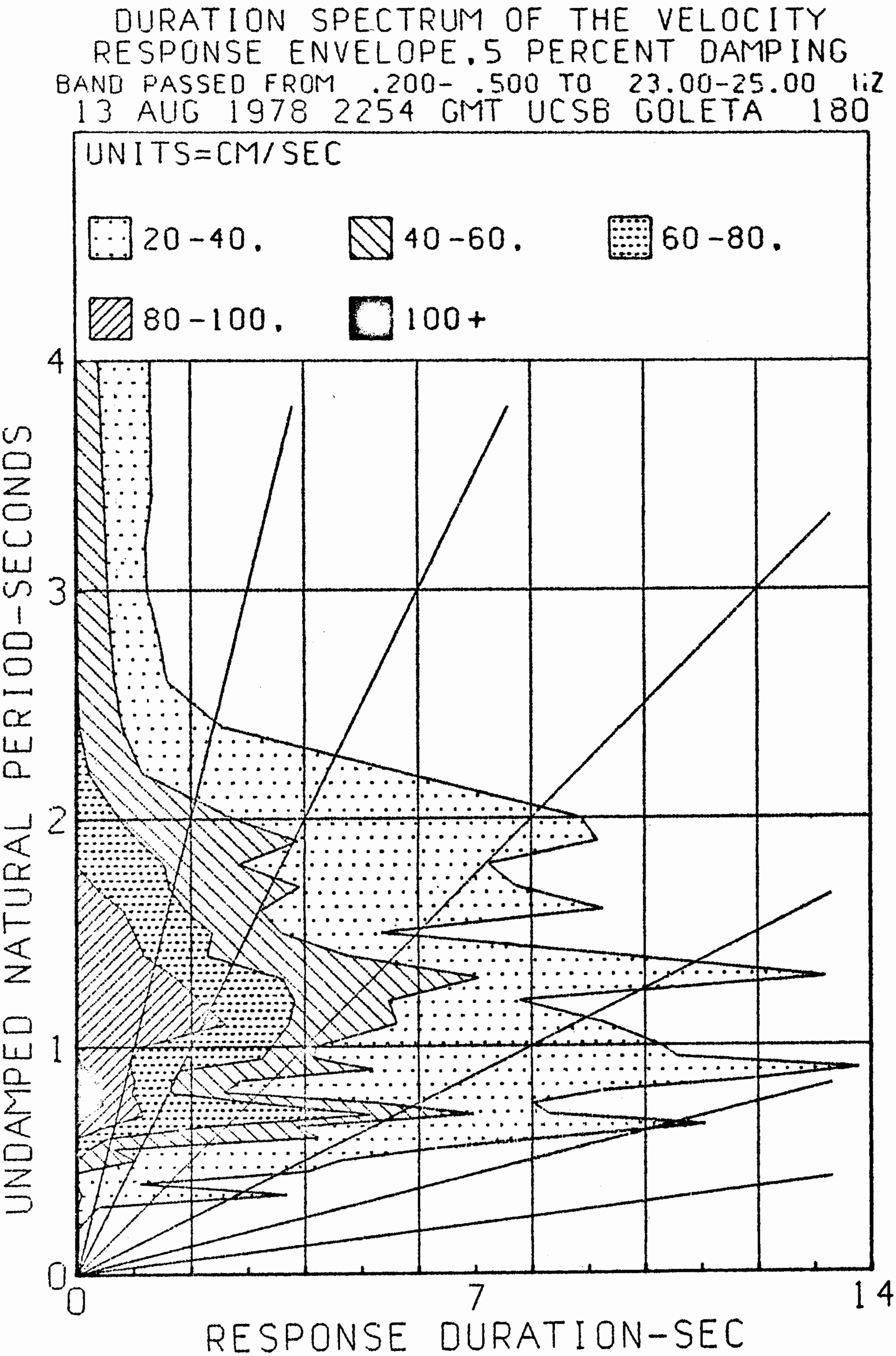

FOURIER AMPLITUDE SPECTRUM OF ACCELERATION
SANTA BARBARA EARTHQUAKE OF 13 AUGUST 1978 2254 GMT
DMG 091 SANTA BARBARA UCSB GOLETA S/N 1607 090 COMP
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
LOG OF FOURIER AMPLITUDE SPECTRUM-CM/SEC
LOG OF FREQUENCY-CPS
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
-1.5
-1.0
-.5
0
.5
1.0
1.5
F_T
F_C
F_C
F_T

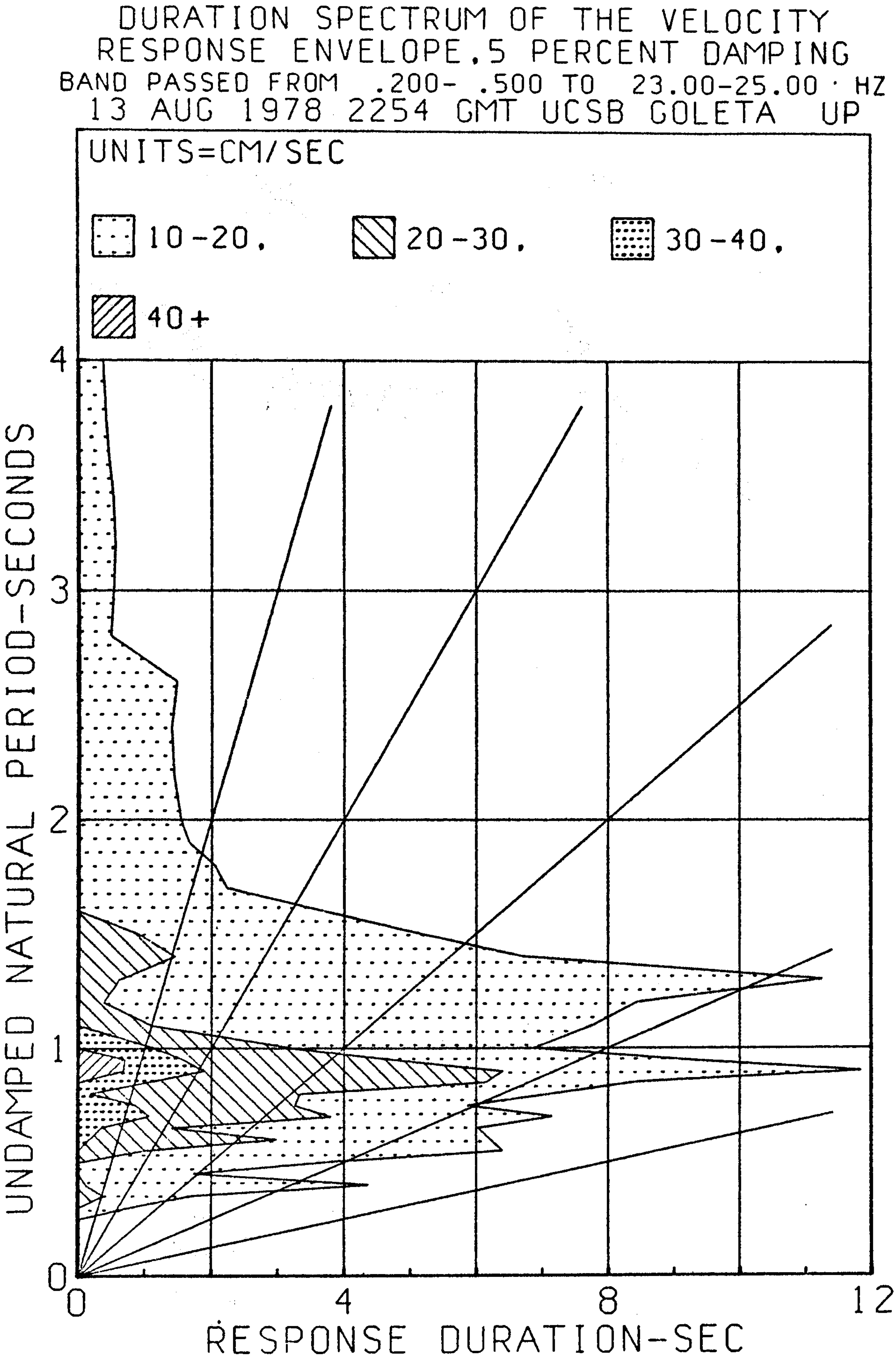

VELOCITY RESPONSE ENVELOPE SPECTRUM,5 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
13 AUG 1978 2254 GMT UCSB GOLETA 180
UNITS=CM/SEC
0-20.
20-40.
40-60.
60-80.
80-100.
100+
VELOCITY CM/SEC
0
150
UNDAMPED NATURAL PERIOD-SECONDS
0
1
2
3
4
TIME - SECONDS
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
ACCEL-G/10
4.
0
-4

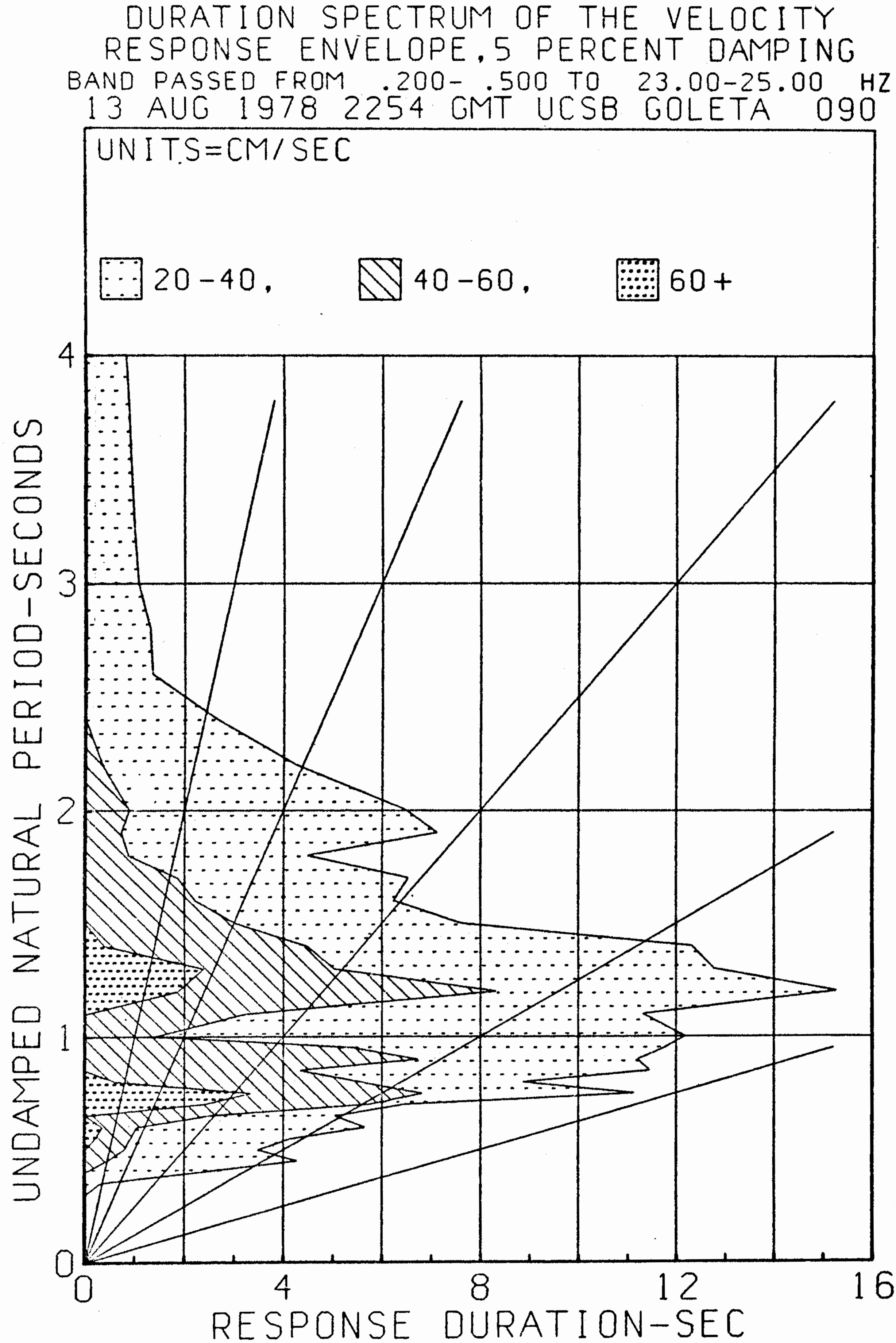

VELOCITY RESPONSE ENVELOPE SPECTRUM,5 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
UNITS=CM/SEC
13 AUG 1978 2254 GMT UCSB GOLETA UP
0-10.
10-20.
20-30.
30-40.
40+
UNDAMPED NATURAL PERIOD-SECONDS
TIME - SECONDS
VELOCITY CM/SEC
ACCEL-G/10



VELOCITY RESPONSE ENVELOPE SPECTRUM,5 PERCENT CRITICAL DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
13 AUG 1978 2254 GMT UCSB GOLETA 090
UNITS=CM/SEC
0-20.
20-40.
40-60.
60
TIME - SECONDS
UNDAMPED NATURAL PERIOD-SECONDS
VELOCITY CM/SEC
ACCEL-G/10


DURATION SPECTRUM OF THE VELOCITY
RESPONSE ENVELOPE,5 PERCENT DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
13 AUG 1978 2254 GMT UCSB GOLETA 180
UNITS=CM/SEC
20-40.
40-60.
60-80.
80-100.
100+
UNDAMPED NATURAL PERIOD-SECONDS
0
1
2
3
4
0
7
14
RESPONSE DURATION-SEC


DURATION SPECTRUM OF THE VELOCITY
RESPONSE ENVELOPE, 5 PERCENT DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
13 AUG 1978 2254 GMT UCSB GOLETA UP
UNITS=CM/SEC
10-20.
20-30.
30-40.
40+
UNDAMPED NATURAL PERIOD-SECONDS
0
1
2
3
4
0
4
8
12
RESPONSE DURATION-SEC


DURATION SPECTRUM OF THE VELOCITY
RESPONSE ENVELOPE, 5 PERCENT DAMPING
BAND PASSED FROM .200- .500 TO 23.00-25.00 HZ
13 AUG 1978 2254 GMT UCSB GOLETA 090
UNITS=CM/SEC
20-40,
40-60,
60+
UNDAMPED NATURAL PERIOD-SECONDS
0
1
2
3
4
0
4
8
12
16
RESPONSE DURATION-SEC